THE THEORY OF THE HANDLING OR WORKING OF Ships at Sea.

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Tranſlated from the Original Printed at *Paris* by the expreſs Command of his Majeſty.

LONDON,
Printed by *J. Humfreys*, for **John Sener**, next the Fleece-Tavern in *Cornhill*, where are to be had all ſorts of Mathematical Books and Inſtruments, both for Sea or Land.

1699

autho

By J. S.

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To the very Ingenious
Edmund Dummer Eſq;
A
Member of Parliament
FOR
Arrundel in *Surry*,
THIS
THEORY
OF THE
Mechanick Part
OF
NAVIGATION
Is moſt Humbly Dedicated,

By *J. S.*

THE PREFACE.

NAVIGATION is ordinarily diſtinguiſh'd in Two Parts, viz Pilotage and the Mecanic: A grea many Perſons have given us Theories of the firſt Part; But I know not of an one which has given us that of the Second It is not becauſe this laſt Part has not at al times been regarded as the moſt eſſential particularly by thoſe that command, becauſ it is from that on which depends the Advantages that may be obtain'd over the Enemy when they are to be attack'd or avoided; whe one is to make the Advantage of the Winds t get off a Lee-ſhore, to double a Cape or a Rock Or in fine, to make any Courſe which ſhall b preſcribed by the Rules of the firſt Part. Bu altho the Mecanic has always been the Object o the principal Application of the Officers, ye they have attained it only by Experience without the help of any Theory, which by conſequence muſt require a great deal of time. I is that which makes me believe this little Wor may be uſeful to thoſe which learn Navigation.

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PREFACE.

As under the Name of the Mecanic Part of Navigation, is comprehended not only the Diſpoſition of the Maſts, Yards, Ropes, and all other Machines, which ſerve on board a Ship, but alſo their particular Uſes: It ſeems, that to give a compleat Theory of the Mecanic Part of Navigation, one ought to have begun with a Deſcription of all theſe things. But to have been able to have given a diſtinct Idea, one muſt have made them to be ſeen upon a Ship, or in a Model which contains them in little; and I do not pretend to ſpeak here of any thing, but what may ſerve as a Principle to the Science of profiting by the Winds the moſt that is poſſible; which wholly conſiſts in determining the moſt advantageous Situation of the Sails, and the Head of the Ship, in relation to the Wind, and the Courſe which is propoſed to be made. This is that which I deſign to ſhew in this Treatiſe, without ſtopping to explicate the particular Uſe of each Mecaniſm, becauſe it will be eaſy after this Knowledge, for any one to attain it without the help of another: But for thoſe which ſhall have occaſion, they may be inſtructed by a Treatiſe, L' exerciſe de la Manævre, *ſet forth by Monſieur* Le Chevalier de Tourville.

In regard to the Conduct of the Work, it muſt be remarked, that the ſimple Truths are demonſtrated by ordinary Geometry; and I have made uſe of Analyſis to find out the more com-

complicated Truths; and where they have appeared very compoſed, I have ſhewn the manner of doing it, and I have given a Mecanic manner of determining them. And that I have neglected Mathematical Exactneſs, when a commodious Proportion has been ſenſibly the ſame as the Truth, which is often neceſſary for Practice.

I have ſuppoſed the Reader to have at leaſt a Knowledge of the Principles of Geometry and Analyſis; So, not to interrupt his Attention, I have paſſed ſeveral particular Demonſtrations.

For to manage it with more Care, I have obſerved in the Figures, to mark in the ſame manner, the Lines which repreſent the ſame things, and when in the ſame Figure, I have been obliged to repeat the ſame Lines differently ſituated, I have prick'd the Lines, and marked them with the ſame Letters as the former, but in a little Character. The Lines which only ſerve for Demonſtration are leſs marked than the others.

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Books, Inſtruments, &c. *Belonging to the Art of Navigation, made and ſold by* John Senex, *next Door to the* Fleece-Tavern *in* Cornhill, *Viz.*

AZimuth, Amplitude, and Meridian Compaſſes, (made after a more correct manner) and all ſorts of Running Glaſſes, Loggs, Logg-Boards, Sea-Plats and Charts, both Plain and Mercator, *&c.*

A new portable Pair of Globes, to be uſed at Sea; the Terreſtrial is laid down, from the moſt accurate *Obſervations*, and neweſt *Diſcoveries* that have been made: Adorned with an uſeful View of the General and Coaſting Trade-Winds, Monſoons, *&c.* The Stars on the Cœleſtial are according to the Obſervations of Captain *Edmund Halley*, Profeſſor of Geometry at *Oxon.* and Mr. *John Hevelius*, Conſul of *Dantzick*; with Nineteen Conſtellations added by them; and never before Printed upon any Globe.

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THE THEORY OF THE Handling, or Working of SHIPS.

CHAP. I.

Of the Force of the Wind against the Sails, and of the Force of the Water against the Rudder, and of its Reſiſtance against the Ship.

ARTICLE I.

ALTHOUGH the Sails of a Ship, or Veſſel, when they are blown out with the Wind, are not flat, yet I ſhall not forbear, at preſent, to conſider them as ſuch, becauſe their moſt advantagious Scituations and Figures will be determined from what ſhall be concluded from plain Superficies.

ARTICLE II.

Fluid Matters, ſuch as are the Air, and Water, are conſider'd, as being compos'd of little Bodies, which move parallel one to the other; ſo that what ſhall be ſaid of one of theſe little Bodies, in regard to a plain Superficie, may be underſtood of all others, becauſe they all encounter this Superficie after the ſame manner.

ARTICLE III.

The Motion of a Body, in regard to a Superficie, may be in three manners Perpendicular, Parallel, or Inclined.

ARTICLE IV.

If the Motion is Perpendicular, as in the firſt Figure, where the Line CD repreſents a plain Superficie, and the Line AB Perpendicular to CD, repreſents the Line which the Body A deſcribes by its Motion, it is evident, that the Body A will puſh with all its force, the Superficie CD, becauſe that it is entirely op-

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poſed to all the Motion of that Body; this Force is called its abſolute Force, which may be expreſſed by the quantity AB, which the Body A runs through, and it will augment, or diminiſh, according as the ſwiftneſs of the Body ſhall augment, or diminiſh.

ARTICLE V.

If the Motion is Parallel, as in the ſecond Figure, where CD repreſents a plain Superficie, and AB, the Line of the motion of the Body A, which is parallel to CD it is evident, that the Body A will not at all puſh the Superficie CD, becauſe that it is no-wiſe oppoſed to its Motion; ſo, whenever the Motion of a Body ſhall be parallel to a Superficie, one may conclude, that this Superficie will not receive any Impreſſion.

ARTICLE VI.

In fine, If the Motion is inclined, as in the third Figure, where CD repreſents a plain Superficie, and AB the Line of the motion of the Body A, which makes with the Superficie CD, the Angle of Incidence ABC; the Body A going from the Point A towards the Point B, may be conſider'd, as having two Motions, in relation to the Superficie CD; the one of which is Perpendicular, and the other Parallel.

DEMONSTRATION.

Let be drawn AE, and BF Perpendicular to CD, and AF parallel to the ſame Line; it is evident, that the Body A going from the Point A to the Point B, is moved in the ſenſe of the Determination AE, the quantity AE, and in the ſenſe of AF, it is moved the quantity AF; the quantity of the Motion AF being parallel to the Superficie CD, by the foregoing Article, does not make any Impreſſion upon this Superficie. There is then nothing but the Motion according to the Determination AE, which makes Impreſſion; but the Superficies is entirely oppoſed to all the motion of this Determination; therefore by the Fourth Article, this Motion will make all its Impreſſion upon it.

It is for this Reaſon, if AB is the Swiftneſs, or the abſolute Force by which the Body A ſhould move to ſtrike a Superficie Perpendicular to the Motion AB; the Line AE is the ſwiftneſs with which the ſame Body A ſtrikes the Superficie CD.

By

By conſequence A E will repreſent the Relative Force of the Body A to the Superficie C D.

If from the Point B, as Center, and with the diſtance A B, a Circle be deſcribed, as in the Fourth Figure, A B will be the Radius, and A E the Sine of the Angle of Incidence A B E. So the abſolute Force of the Body A is to its Relative Force to the Superficie C D, as Radius is to the Sine of the Angle of Incidence. It is the ſame in regard to all Superficies, diverſly inclined to the motion of this Body; therefore the relative Force to theſe Superficies are between themſelves, as the Sines of their Angles of Incidence.

ARTICLE VII.

If there were then an equal number of little Bodies, of a fluid Matter, which did ſtrike againſt two, or more Superficies diverſly inclined, the Relative Forces of this Matter to theſe Superficies, would be between themſelves in the ſame Proportions as thoſe of one only Body; that is to ſay, as the Sines of their Angles of Incidence. But there is a greater number of thoſe Bodies which ſtrike thoſe Superficies which are leſs inclined, than thoſe which are more; and this alſo in proportion of the

Sines of the Angles of Incidence; therefore theſe Relative Forces will be between themſelves in a Duplicate Ratio of the Sines of their Angles of Incidence, or which is the ſame thing, as the Squares of thoſe Sines are among themſelves.

DEMONSTRATION.

Let there be in the Fifth Figure the Circle C A G, of which let B be the Center, C D repreſenting a Superficie, to which let the Line of Motion A B be Perpendicular, G E repreſenting another Superficie inclined to the Motion A B, of which the Angle A B E is the Angle of Incidence. Draw the Lines C L, G N, B A, P O, and D M Parallels, one to the other, and E F parallel to C D. It is evident, that all the little Bodies, or all the fluid Matter which is contained between the Lines C L, and D M, do ſtrike Perpendicularly the Superficie C D, and that there is nothing but what is contained between the Lines Q N, and P O, which ſtrike againſt the Superficie E G.

Theſe two quantities of Matter are between themſelves, as the Space contained 'twixt the two firſt Lines, is to the Space contained between the two latter; that is to ſay, as C D is to P Q, or, as A B, is to

F E,

FE, which are their halves; or, in fine, as Radius is to the Sine. But by the foregoing Article, each of thoſe little Bodies ſtrike more ſtrongly the Superficie C D, than the Superficie E G, and in the ſame Proportion, as Radius to this Sine.

Therefore this fluid Matter ſtrikes the Superficie C D, ſtronger than it does the Superficie E G, in a Duplicate Ratio of Radius, to the Sine of the Angle of Incidence; that is to ſay, as the Square of Radius to the Square of the Sine of the Angle of Incidence.

Whence it follows, That the Relative Forces of a fluid Matter, to Superficies diverſly inclined, are between themſelves, as the Square of their Angles of Incidence; which was to be demonſtrated.

ARTICLE VIII.

A Superficie receives no Impreſſion, but according to a Line which is Perpendicular to it, by the Sixth Article. So in the Fourth Figure, the Body A makes no Impreſſion upon the Superficie C D, but in the Determination A E, which is Perpendicular to it. The Point B of this Superficie, which is ſtruck in this ſenſe, is puſh'd towards G, according to the Line B G, and it is the ſame with all the other Points. By conſequence, how much ſoever the Motion of any Matter be inclined, in regard to a Superficie; this Superficie will be determined to move in the ſame manner, as if the ſame quantity of Matter ſhould ſtrike it Perpendicularly, with the Swiftneſs expreſſed by the Sine of the Angle of Incidence; that is to ſay, with a Swiftneſs which is to its abſolute Swiftneſs, as the Sine of the Angle of Incidence is to Radius.

ARTICLE IX.

Conſidering the Sail as a plain Superficie, and the Air being a fluid Matter, the Forces with which the Wind will puſh a Sail diverſly ſituated, will be betwixt themſelves, as are the Squares of the Sines of the Angles of Incidence, and the Sail will be puſhed according to a Line which will be Perpendicular to it.

ARTICLE X.

The Rudder alſo being a plain Superficie, and Water a liquid Matter, the forces with which the Water will puſh the Rudder, will be betwixt themſelves, as are the Squares of the Sines of the Angles of Incidence, and the Rudder will be puſhed according to a Line which will be Perpendicular to it.

ARTICLE XI.

Of the different Impreſſion the Wind makes againſt the Sails, and the Water againſt the Rudder, I have only conſidered thoſe which ariſe from the divers Situations that the Sail, or Rudder may be put in, and not thoſe which are cauſed by the different ſwiftneſs of the Wind, or Water, becauſe there is occaſion only to know the Relations of the Impulſions of the Winds againſt the Sails, and of the Water againſt the Rudder diverſly inclined, ſeeing theſe Relations do not change at all, whatever Change happens to the ſwiftneſs of the Wind or Water.

ARTICLE XII.

And if one conſiders the Impulſions which ariſe from the different Swiftneſſes of a fluid Matter, againſt Superficies ſituated in the ſame manner, he will find they are 'twixt themſelves, as the Squares of the Swiftneſſes of that fluid Matter. For not only each Particle of the fluid Matter ſtrikes more or leſs ſtrong, in proportion to its ſwiftneſs, but alſo the number of the little Particles which ſtrike in an equal time, are more or leſs Great in proportion to their Swiftneſs. By conſequence this Impulſion is in a Duplicate Ratio, or that which is the ſame thing, in proportion to the Squares of their Swiftneſſes. So that if a fluid Matter hath a triple ſwiftneſs of another, its Impulſion will be nine times as great, becauſe in an equal time it will have three times as much Matter, which will puſh this Superficie, and each Particle having a triple Swiftneſs, it will puſh three times as ſtrong: ſo the whole Matter will make an Impulſion nine times as great.

ARTICLE XIII.

It is indifferent whether you conſider the motion of a ſolid Body in an immovable fluid Matter, or the Motion of a fluid Matter againſt a ſolid Body, which is at reſt, the reciprocal Impreſſions being always the ſame; ſo that if a ſolid Body be moved with unequal ſwiftneſſes in any fluid Matter, as in the Water, the different reſiſtances which it will receive from the Water, will be in the ſame Proportion, as the Squares of the Swiftneſs of that Body.

Whence it follows, That to cauſe a Body to move with different degrees of Swiftneſs, in a fluid Matter, it is neceſſary that the Powers which cauſe it to move, ſhould have the ſame Ratio as the Squares of their Swiftneſſes.

ARTICLE XIV.

Now, if one would examine the different ſwiftneſs of a Ship, in relation to the different Angles of Incidence of the Wind upon the Sail, one ſhall find, that theſe Swiftneſſes are in the ſame Ratio as the Sines of the Angles of Incidence.

For by the Ninth Article the Forces of the Wind upon the Sail, are as the Squares of the Sines of the Angles of Incidence; and by the preceding Article, the Forces or the Powers which cauſe a Ship to move, are as the Squares of the Swiftneſſes which they impreſs on the Ship.

Therefore, the Squares of the Sines are as the Squares of the Swiftneſſes, and by conſequence, the Swifneſſes of a Ship are as the Sines of the Angles of Incidence of the Wind on the Sail.

CHAP. II.

Of the Motion of a Ship in general, and of the manner of knowing her Drift, or Lee-Way.

LET there be in the firſt Figure the Ship H M, the ſtrait Line C D repreſenting the Superficie of a Sail; the ſtrait Line A B repreſenting the Wind, which goeth from A towards B; let alſo the Line B G be Perpendicular upon C D, and G K Perpendicular upon B K the Keel of the Ship prolonged.

By the Eighth Article of the preceding Chapter, the Superficie C D is puſhed by the Wind A B, according to the Line B G. So if the Ship ſhould divide the Water every way, with the ſame facility that it does the Water with its Stem, it would go to the Point G, along the Line B G; in running this Line, it would advance right forward the quantity B K, and Side-ways the quantity K G. But as a Ship is a great deal longer than broad, it finds a great deal more difficulty to ſplit the Water with its Side than with its Stem; ſo that in the Determination K G, it does not advance the quantity K G, there will want a quantity proportional to the difficulty, which it has more to divide the Water with its Side, than with its Stem: In ſuch manner, that, for Example, Suppoſe the difficulty that the Ship finds to ſplit the Water with her Side, is to that which ſhe finds to ſplit it with her Stem, as ten to one, the Ship will not advance in the Determination K G more than the tenth part of K G. Therefore if K G, be proportioned to K L, as the reſiſtance of the Side to the reſiſtance of the Stem, and the Line B L be drawn; the Ship will go to the Point L, according to the Line B L, in the ſame time that it would have been in the Point G, if it ſhould ſplit the Water on all Sides with the ſame facility.

The part K L is called the Drift, or Lee-way of the Ship, B L the true Courſe of the Ship, the Angle K B L, the Angle of the Drift, *or how many degrees Lee-way ſhe makes*; the Angle A B K, the Angle of the quantity which the Ship preſents to the Wind, *or how near the Wind ſhe lies*; and when this Angle is more ſharp, we ſay the Ship preſents more to the Wind, *or lies nearer the Wind.*

From all which it follows, that if one knows the relation there is 'twixt the Reſiſtance which the Ship finds to ſplit the

Water Sideways, to that ſhe finds to ſplit the Water with her Stem, then one might determine the Line of the true way of the Ship; but as it would be very difficult to determine this Relation from the knowledge of the Figure, and proportions of a Ship, ſee here a Method whereby it may be known.

ARTICLE II.

Let in the ſecond Figure, G, C, D, F, be four Points on the Shore ſide, A and B, two Compaſſes, A D and B E repreſenting the Lines of North and South, and the right Line A B C, which paſſes through the two Centers a North-Eaſt and South-Weſt Line; theſe two Lines A D, and B E, although they regard directly the North Pole, yet, as the diſtance A B is inſenſible, in relation to the diſtance of theſe two Compaſſes from the Pole, theſe two Lines A D, and B E, may be regarded as Parallels; ſo the Angle D A C is equal to the Angle E B C, and by conſequence the Point C on the Shore, is in the ſame Situation in regard to the two Compaſſes, *or it bears upon the ſame Point of the Compaſs from* A *and* B. There is therefore no other Point on the Shore which is in this manner, for if you take another Point, as F, it is vident, that the Angle F A D is more harp than the Angle F B E; and by conquence, the Point E is not at all in the me Situation, in regard to the two Comſſes.

If you take the Point D, which is North om the Compaſs A, you will ſee that it akes an Angle D B E, with the North of e Compaſs B; alſo, if you take the oint G, which lies Eaſt from the Comſs B, and makes a right Angle with the orth of this Compaſs, as G B E, you ill find, that this Point makes with the orth of the Compaſs A the Angle G A D fferent from G B E; it will be the ſame ith all other Points on the Shore.

It follows from all this, that a Ship beg in ſight of Land, and ſteering towards this Land, or going directly from there will be one Point on the Shore, hich will not at all change its Situation, regard to the Compaſs that ſhall be on oard the Ship.

ARTICLE III.

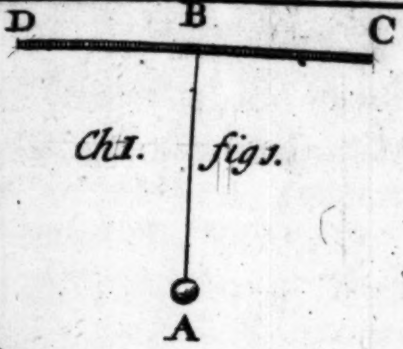
From the foregoing it is eaſie to deternine the Relation of the Reſiſtance which Ship finds to ſplit the Water with its ide, to that it finds to ſplit it with its tem.

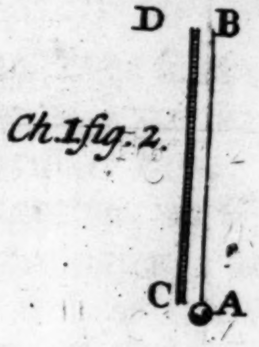
For this purpoſe, let there be in the thir Figure the Ship B M, the Line A B repre ſenting the Wind, the ſtrait Line C D re preſenting the Superficie of the Sail, th Line B M the Keel of the Ship, let th Line B G be Perpendicular upon C D the Line G K Perpendicular upon B M prolonged, and B L the Line of the Ship true way found by the preceding Article which cuts G K at the Point L.

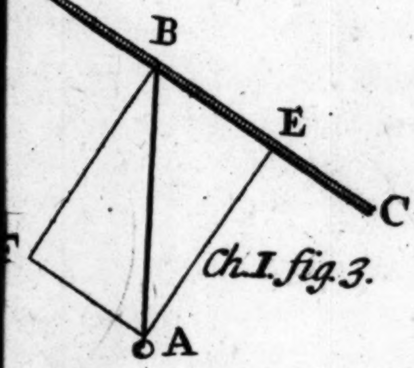
It hath been ſaid, that if a Ship ſhoul ſplit the Water every way with the ſam facility that it does with the Stem, ſh wou'd make her way towards the Poin G along the Line B G, and would mak her way Sideways, according to the Determination K G, the quantity K G, but a ſhe goes but to the Point L, ſhe makes he way Sideways no more than the quantity K L, ſo that it finds more difficulty to ſpli the Water with its Side than with its Stem in the ſame proportion that K G is greate than K L; therefore the difficulty which the Ship finds to move through the Wate Sideways, to that which it finds to mov Endways, is as K G to K L.

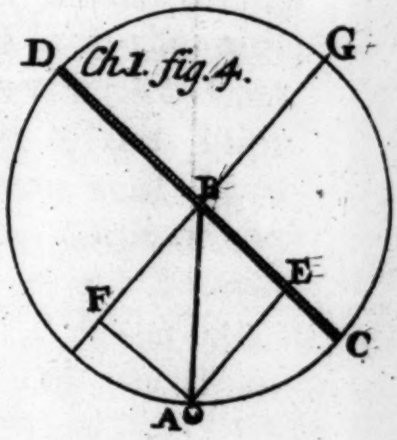
ARTICLE IV.

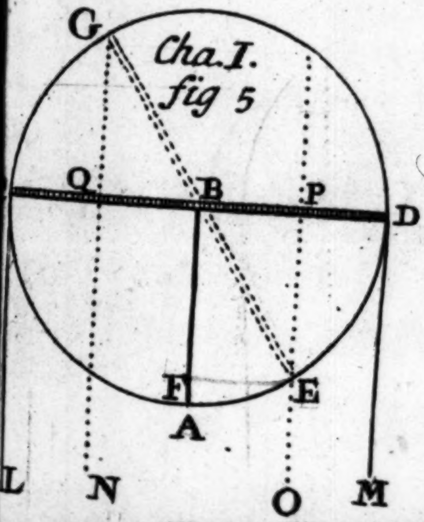
This Relation once known, will always ſerve to determine the Line of th

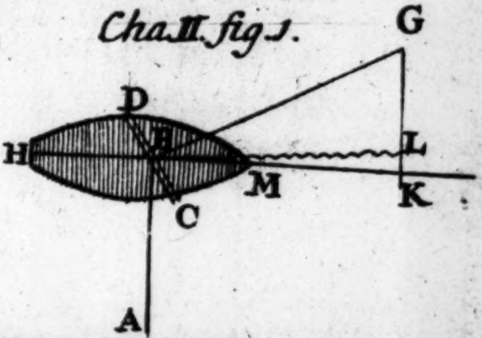

Ch.I. fig.1.

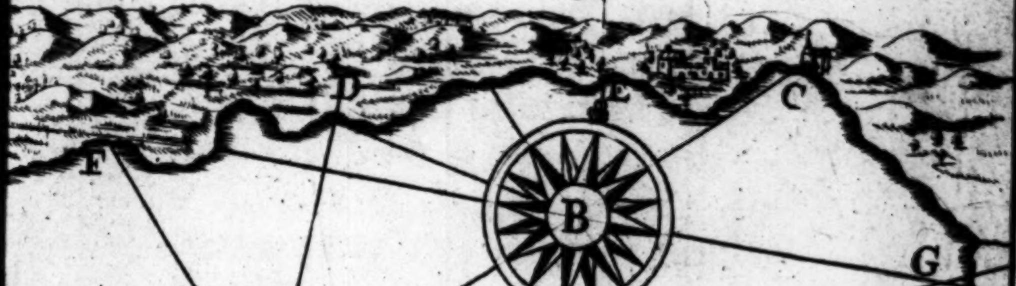

Ch.I. fig.2.


Ch.I. fig.3.


Ch.I. fig.4.


Cha.I. fig 5


Cha.II. fig.1.


Cha.II: fig.2.

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hips true way, for in whatſoever ſcituati-
n you put the Ship and the Sail, you have
nly to erect a perpendicular Line, as
G upon the Sail C D, another, as G K
erpendicular to the Keel prolonged; and
make that G K is unto K L as the re-
ſtance of the ſide is to that of the Stem,
nd from the point B, which is in the mid-
le of the Sail, and to draw the right Line
L, which will be the Line of the Ships
ue way; By this means you will have
e quantity of the Drift, the Angle of the
rift, that is, *how many degrees Lee-way*
e makes, the quantity the Ship pre-
nts to the Wind, *or how near the Wind*
e Ship lies, and you may know whether
u ſhall double a Cape or a Rock, or, if
u can gain the place where you would
; for you have only to examine if the
ne of the true way is to Windward or
Leeward of the place you would gain.

ARTICLE V.

Hitherto we have ſuppoſed that the
ip moves parallel to its ſelf, that is to
, that its Keel is always directed by the
dder along the Line B M, or upon a-
her Line which is parallel to it; ſee
e the manner how the Rudder cauſes
s effect.

DEMONSTRATION.

Let in the *4th* Figure, D M be the Figure of the Ship, D C repreſenting the Rudder, B G perpendicular on the Rudder, M D prolonged in G, and from the point B, which is in the middle of D C, let fall B F perpendicular to D G. The Ship moving forward according to the determination D M, by conſequence the Water ſtrikes the Rudder after the ſame manner as if the Ship were at reſt, and the Water moving from forward aft, in the determination M D or A B, which are parallels, of the ſame quickneſs as the Ship goes a head. By the *8th* Aricle of the preceeding Chapter, the Water which comes from A towards B, along the Line A B, puſhes the Rudder along the Line B G. By the *6th* Article of the ſame Chapter, if B G repreſents the force with which the Rudder is puſhed, B F will be the force with which it is puſhed in the determination B F, and F G that with which it is puſhed in the determination F G. But as the Rudder is faſtened to theShip by the point D, the Ship is alſo puſhed the ſame quantities according to theſe two determinations; in ſuch manner that the point D will move towards K

nd the point M towards Z; the way of
ach of theſe two points will be greater or
ſſer, according to the place where the
Center of gravity of the Ship is: If for ex-
mple it was in the point O, the way
which the point M makes towards Z, will
e to that which the point D makes to-
wards K, as M O is to O D. There-
ore, by the means of the Rudder one may
rect the Stem of the Ship, and ſo may
eep the Ship parallel to its ſelf, in keeping
e Ships head always on the ſame point
f the Compaſs.

CHAP. III.

f the manner of knowing whether you are to Windward or to Leeward of another Ship under Sail.

ARTICLE I.

E T the Lines A B, N C, and O D,
(in the firſt Figure) be Parallels, re-
eſenting the Wind going from A to-
ards B, and let there be two Ships C and
. If from one of theſe Ships you draw
e Line C D (with the Compaſs of Va-
tion) perpendicular to the Line of the

Wind A B, and that this Line alſo meet with the other Ship, theſe two Ships ar equally to Windward, that is to ſay, i they ſhould come to encounter one another, with the like circumſtances, the would meet in one and the ſame point.

DEMONSTRATION.

Let the Angle N C H be the quantit the Ship C preſents to the Wind, *or how near the Ship lies*, the Angle O D I, the quantity the Ship D preſents to the Wind, and the Angle H C L, the Angle of th Drift *or Lee-Way the Ship C makes*, the Angle I D L the drift of the Ship D, let th Line C L be the true Courſe of the Shi C, and the Line D L the true Courſe o the Ship D. By the Hipotheſis, the Angle N C D and O D C, are right, and, b reaſon of like Circumſtances, the Angle N C L is equal to the Angle O D L, the Angle L C D will therefore be equa to the Angle L D C, and the Line C L equal to the Line D L. By conſequenc the two Ships going equally Swift, muſ in the ſame times run over equal Lines, and they muſt meet in the ſame Point L.

ARTICLE II.

If the Line C E, which is drawn from the Ship C, perpendicular to the Wind, does not meet the Ship D, as in the ſecond Figure, and that this Line paſſes on that ſide from which the Wind comes, the Ship C will be to Windward of the Ship D, the quantity E D, that is to ſay, the quantity the Line C E is diſtant from the Ship D.

DEMONSTRATION.

Let, the Line D P be perpendicular to the Line of the Wind A B, the two Lines P L and D L, which meet in the Point L, and make equal Angles with the Line D P, and let C *l* be Parallel to P L. By the foregoing Article, if the Ship C were at the Point P, it would meet the Ship D in the Point L. But in the time which the Ship C would go from the Point P to the Point L, it goes from the Point C to the Point *l*, becauſe that C *l* is parallel to P L; the Ship C will therefore find it ſelf at *l*, when the Ship D will find it ſelf at L. Conſequently the Ship C will be to the Windward of the Ship D, the quantity *l* L, C P, or E D, which are three equal Lines.

ARTICLE III.

You will ſee by what follows, what it is to be above the Wind, *or to Windward,*

below

below the Wind, *or to Leeward*, and equal to the Wind, and what it is to hold the Wind equally; for two Ships holding equally the Wind, when they are once upon the ſame Line perpendicular to the Wind, will always keep ſo, as long as they continue their Way, or when they are not in the ſame Line perpendicular to the Wind, they will always keep the ſame Inequality.

ARTICLE IV.

Two Ships which are equally to Windward, that is to ſay, upon the ſame Line perpendicular to the Wind, may always keep ſo, and meet each other in the ſame Point, although the Courſe they go do not make equal Angles with the Wind, *or that the one does not lie ſo near the Wind as the other*; provided that the Swiftneſſes of the Ships are in the ſame proportion as the diſtances of their run, which we ſuppoſe terminated in their Point of meeting.

DEMONSTRATION.

Let there be in the third Figure, two Ships C and D upon the Line C D, perpendicular to the Wind, the Angle N C H leſs than the Angle O D I. If the

Swiftneſs of the Ship D, upon the Line D L (along which it runs) is to the Swiftneſs of the Ship C, upon the Line C L, as the length of the Line D L, is to that of C L, they will be always equally to Windward. For in what time ſoever you conſider theſe two Ships, the Ship C will have run the ſame quantity of the Line C L, as the Ship D, of the Line D L; ſo that the right Line which ſhall be drawn from one of theſe Ships to the other, Cutting in like proportion the Sides C L and D L of the Triangle C D L, will be parallel to the Baſe C D, and conſequently perpendicular to the Wind. In ſuch manner that theſe Ships will be always equally to Windward, holding equally the Wind in inequal Circumſtances, and will meet at the Point L.

ARTICLE V.

Two Ships may hold equally the Wind, although they neither are equally to Windward, nor make the one to the other with equal Circumſtances. This will happen when they keep always the ſame Inequality between them, which you will ſee plainly if you conſider what has been ſaid in the foregoing Articles.

CHAP. IV.

Of the Manner of determining the mo
advantageous Situation of the Sails an
Head of the Ship, to hold the Win
the moſt that is poſſible.

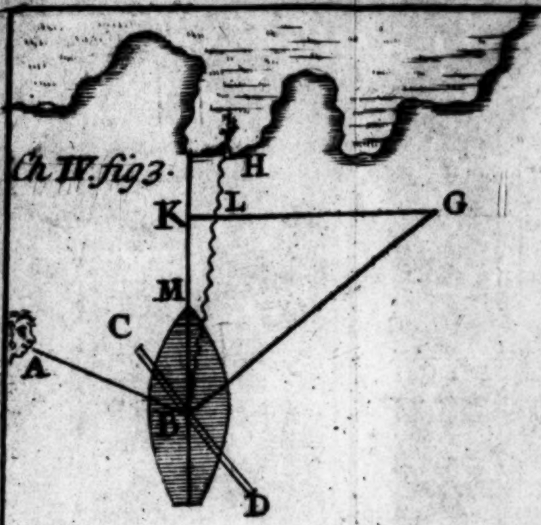
ARTICLE I.

LET in the firſt Figure, the Line A
be the Line of the Wind, whic
goes from A towards B, B the Ship, B
the Keel prolonged, C D the Sail, B
perpendicular upon C D, G K perpendi
cular upon B K, and let G K be cut a
the Point L, in ſuch manner that K G, b
to K L, as the reſiſtance which the Shi
finds to divide the Water with its ſide, i
to that which ſhe finds to divide it wit
her Stem, and draw the Line B L, whic
will be the true Courſe of the Ship. Ta
king another Situation of the Sail, as *c*
from the Point B, and with the inetrva
B G, deſcribe the Circle G A; erect th
Perpendicular B *g* upon *c d*, *g k* per-
pendicular upon B *k*, draw B *l* in th
like Circumſtance as B L, and B *l* will be

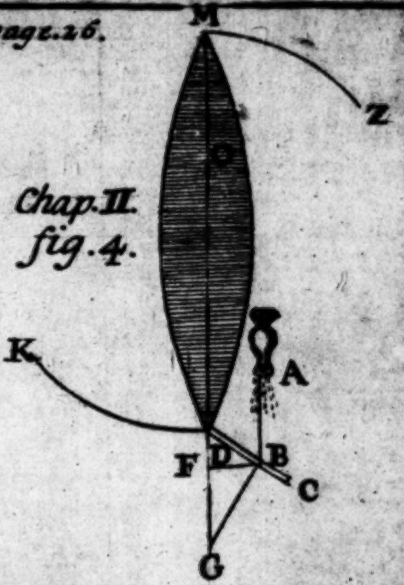
the true Courſe of the Ship in the ſecond Situation of the Sail; prolong C D into R, and *c d* into *r*, draw *l* O perpendicular to the Wind, which cuts B L, in P, draw alſo A V the Sine of the Angle of Incidence A B R, and A *u* the Sine of the Angle of Incidence A B *r*. By the firſt Article of the ſecond Chapter, the Sail being in the Situation C D, the Ship will go to the Point L, in the time it would have been at the Point G, if it ſhould ſplit the Water on all ſides with the ſame facility it finds to ſplit it with the Stem foremoſt. By the ſame reaſon, the Sail being in the ſituation *c d*, the Ship will go to the Point *l* in the ſame time it would have been at the Point *g*; but B G being equal to B *g*, if the Ship were puſhed equally in theſe two ſituations of the Sail, it would run in an equal time to the Point L, or to the Point *l*, and by conſequence it would go more to Windward, when the Sail being ſituated according to C D, it would make her hold her Courſe according to B L, than when the Sail being according to *c d*, the Ship holding her Courſe in B *l*. But to the end that the Ship do keep equally to Windward in theſe two ſituations of the Sail, ſhe muſt arrive at the ſame time to the Point P and to the Point *l*; and for this effect, the ſwiftneſs of the Ship, when the Sail CD makes it keep the Courſe B L, ought to be leſs than when the Sail *c d* makes it keep the Courſe *B l*, in the proportion of B P to B L, that is to ſay, by the 14*th* Article of the firſt Chapter, it muſt be that the Sine A V of the Angle of Incidence A B R, ſhould be to the Sine A *u*, as B P, is to B L. And if the Ratio of A V to A *u*, is greater than that of B P to B L, the Ship will go more to Windward in the ſituation of the Sail C D, than in the ſituation *c d*, if the Ratio is leſs, it will keep the Wind more with the Sail *c d*.

ARTICLE II.

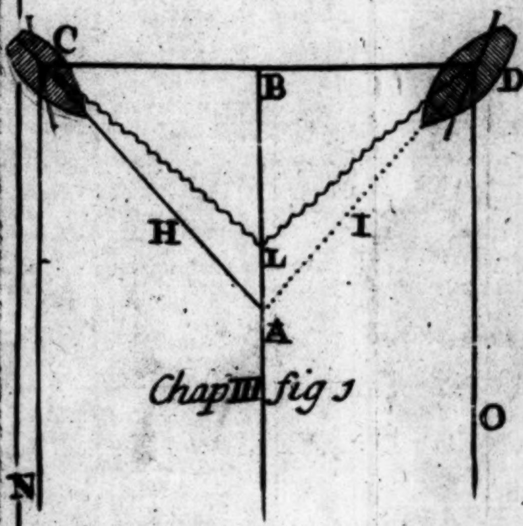
In the ſecond Figure, let R M repreſent the Ship, C D the Sail, A B the Line of the Wind, B G perpendicular upon C D, G K perpendicular upon B M prolonged, B L the Line of the Ships Way. Let there be another ſituation of the Ship *r m*, the ſame ſituation of the Sail C D, the Lines *g k* and B *l*, drawn in the ſame Circumſtances, *as the Line B L*, and let *l* O be drawn perpendicular to the Wind. By the firſt Article of the Second Chapter, the Ship in the ſituation R M, goeth to the Point L, in the ſame time that it would to the Point G, if it did divide the Water on all ſides, with the ſame facility that it does page. 26.



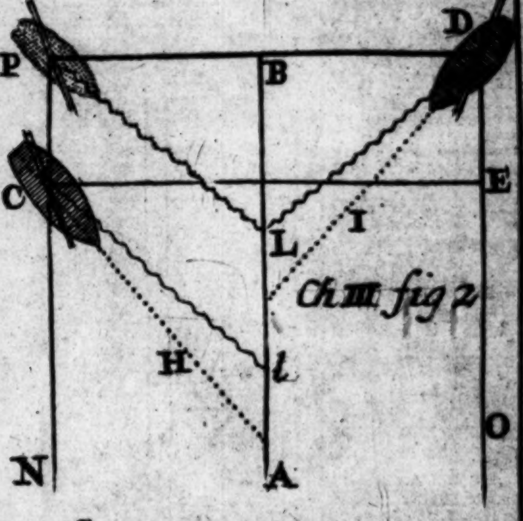
Ch. IV. fig 3.



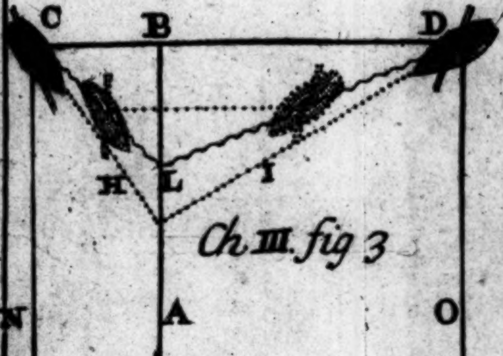
Chap. II. fig. 4.



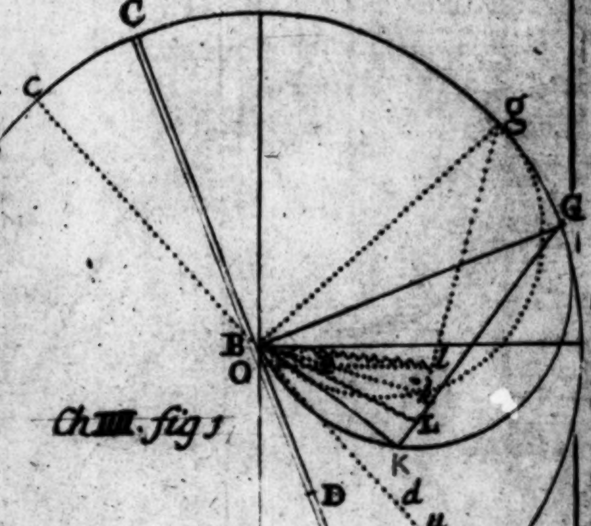
Chap III fig 1



Ch III fig 2



Ch III. fig 3



Ch IIII. fig 1

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with the Stem. The Ship in the ſituation r m, will alſo go to the Point l in the ametime. The Ship in the ſituation R M, will therefore go to the Point L, in the ame time that it would have been at the Point l in the ſituation r m. In fine, that he Ship may keep to Windward equally n theſe two ſituations, the Line l O muſt paſs by the Point L; if the Line l O paſſes o Windward of the Point L, the ſituation r m will be more advantageous than he ſituation R M, if the Line l O paſſes o Leeward of the Point L, the ſituation R M will be moſt advantageous.

ARTICLE III.

By the foregoing Articles it follows, that he diverſe ſituations of the Sail of a Ship, nay cauſe a Ship to keep more or leſs to Windward; and the diverſe ſituations you nay put the Ship in without changing the ail, may cauſe the ſame Effect. It may herefore be demanded in what manner ou will ſituate the Sails and Head of the hip, to the end it may go to Windward he moſt that is poſſible. You muſt know, n the firſt place, that in whatſoever ſituation you put the Sail, the ſituation of the hip muſt always be in the Line, which cuts in two equal parts, the Complement of the Angle of Incidence of the Wind u on the Sail. So that in the third Figur if A B is the Wind, to which let B E b perpendicular, C D a ſituation of the Sai A B C its Angle of Incidence, C B E th Complement of A B C ; the moſt advantageous ſituation of the Ship is accordin to the Line B K, which cuts the Angl C B E into two equal parts.

DEMONSTRATION.

Let, B G be perpendicular to C D, an with the interval B G, and from the Poin B as Center let be deſcribed the Circle AG and, from the Point F (in the middle o BG) as Center, and with the Interval F deſcribe the Semicircle BKG ; and from let fall the perpendicular F K upon B E and from the Point K the Line K Z perpendicular to the Wind, draw the Line B K, G K, and after having divided K G a Cuſtomary in L, draw B L, which will b the Way of the Ship, take another Point k and draw B k, G k, and B l, in the ſam Circumſtance as above ; and alſo draw K k and L l. By the Firſt Article of th Second Chapter, and by the firſt of this here, the Ship in the ſituation B K, wil go to the Point L, in the ſame time i would have been at the Point l, in the ſiuation B *k*. The Arch B K H is cut in wo equally at the Point K, becauſe the Line F K is perpendicular to B H; therefore the Line B K cuts alſo the Arch B K H n two equal parts. Seeing that the Line K Z is perpendicular to the Wind, and by onſequence to F K Semidiameter of the Circle B K G, it will not touch this Circle ut in the Point K, and all other Points *k*, vill be to Leeward of the Point K; the Line L *l*, cutting proportionally the ides G K, and G *k*, by reaſon the Leeways are alike, it will be parallel to the Line K *k*, and by conſequence the Point *l* vill be to Leeward of the Point L. And s the ſame thing will be concluded from all ther Points, the ſituation B K of the Ship vill therefore be the moſt advantageous.

ARTICLE IV.

Seeing the ſituation of the Ships Head lepends on that of the Sail, the whole will e determined, if the moſt advantageous ituation of the Sail is known; and to now it, let in the Fourth Figure, A B e the Line of the Wind, C D one ſituation of a Sail, *c d* another ſituation of a ail. From the Point B as Center, and with he Interval A B taken at Diſcretion, eſcribe the Circle A C G. Draw B E erpendicular to the Wind, B G perpendicular to the Sail C D, from the Point the middle of B G, deſcribe the Semicircl B K G, which cuts B E in the Point H, Cut the Angle C B E into two equal part by the Line B Y, which will cut the Arch B H in two equal Parts at the Point K, the Line B Y will by the preceeding Article be the moſt advantageous ſituation o the Ship; draw the Line G K, and make K L to K G, as the reſiſtance which th Ship finds to divide the Water with it Stem, is to that ſhe finds to divide i with her ſide; draw B L which will b the Courſe of the Ship, by the firſt A ticle of the Second Chapter; in fine, draw the Line A V, the Sine of the Angle of In cidence of the Wind upon the Sail. Draw in the ſame Circumſtances as foregoing, the Line B *g* perpendicular to *c d*, the Semicircle B *kg*, and the Lines B *k*, and B *l*, the Line B *l* will be the moſt advantageous ſituation of the Ship in regard to the Sail *c d*, B *l* will be the true Courſe, and A *u* the Sine of Incidence. From the Point *l* draw *l* & parallel to B E which cut B L in &. By Article the Firſt, to the en that the Ship may keep the Wind equally in the two Situations of the Sail C D, an *c d*, it is neceſſary that the Sine of the An gle of Incidence A V, be to the Sine A *u*, a B & is to B L, and if the Ratio of A V, o A *u*, is greater than that of *b* B, to B L, he ſituation C D of the Sail will be more advantageous than the Situation *cd*; ſo that f one can find the ſituation of a Sail as C D, which ſhould be ſuch that (the ing the conſtruction as above) the Ratio of the Sine A V, to all other Sines A *u*, hould be greater than that of the Line B *b* to B L; this ſituation C D of the Sail will be the moſt advantageous for to get to Windward; and for to determine it, rom the Point G, and the Center F of he Circle B K G, draw the Lines G H and K F, which will be perpendiculars to B E, he Lines G Q, F X, and L N, Parallels o B E, and L R, or Δ, perpendiculars to B E. And let be drawn in the ſame Circumſtances the Lines *g h*, *f k*, *g q*, *f x*, *ln*, *lr*.

The Angles A B E, and C B G are equal, becauſe they are right, taking away the Angle C B E which is common to both, he Angle G B E is equal to the Angle of Incidence A B C; by conſequence G H is equal o A V. By the like reaſoning *g h* is equal to *u*. So that if one ſuppoſe the Radius B G, or $Bg = a$, the Sine of the ∠ of Incidence A V or $GH = x$, another Sine of Incidence A *u*, or $gh = x - y$, ſuppoſing that he difference of G H to $gh = y$.

The Line F X cuts equally in two GH, ſo that G X, or F Q, or F P$=\frac{1}{2}x$, F G or F K$=\frac{1}{2}a$. Therefore P K$=\frac{1}{2}a-\frac{1}{2}x$.

By the ſame way of reaſoning, one ſhall find that $kp=\frac{1}{2}a-\frac{1}{2}x+\frac{1}{2}y$.

It has been ſaid, to the end that a Ship might keep equally to Windward in the two ſituations of the Sail C D, and *c d*, that then, the Sine of AV to A *u*, muſt be as the Line B & is to the Line B L; or that which is the ſame thing, that the Sine AV, be to the Sine A *u*, as & △, is to L R, becauſe that & △ and L R being parallels, B &, is to B L, as & △, is to L R. For to find the value of L R and of & △, I ſuppoſe that the reſiſtance that the Ship finds to ſplit the Water with its Side, is to the reſiſtance that it finds to do it with its Stem foremoſt, as *c* is to *b*. And becauſe that L N is parallel to G Q, it follows that Q K is to K N, as G K, is to K L, that is to ſay, as *c* is *b*. But K Q$=$K F$+$F Q or$=\frac{1}{2}a+\frac{1}{2}x$. Therefore as *c* is to *b*, ſo $\frac{1}{2}a+\frac{1}{2}x$ is to $\frac{ab+bx}{2c}=$N K, taking N K from P K, one ſhall have $\frac{1}{2}a-\frac{1}{2}x\;\frac{-ab-bx}{2c}=$P N or L R. By the ſame train of reaſoning one ſhall find that *p n*, or & △$=\frac{1}{2}a-\frac{1}{2}x+\frac{1}{2}y\;\frac{-ab-bx+by}{2c}$. The two Lines & △ and L R being found, you muſt make this Analogy as the Sine of A V, is to the Sine of A x, ſo the Sine △ & is to the Line L R, or you may make ſe of the Analitique terms. $x . x-y :: \frac{1}{2}a-$ $x+\frac{1}{2}y$ $\frac{-ab-bx+by}{2c}$. $\frac{1}{2}a-\frac{1}{2}x$ $\frac{-ab-bx}{2c}$. Multiplying he two laſt Terms by $2c$, the proportion loes not change at all, and you will have $. x-y :: ac-cx+cy-ab+by-bx . ac-$ $x-ab-bx.$

Multiplying the two Extreams, and the wo means, you will have this Equation,

$$\left.\begin{array}{l} acx-cxx \\ \\ -abx-bxx- \end{array}\right\} = \left\{\begin{array}{l} acx-cxx+2cxy \\ -abx-bxx+2bxy \\ -acy-cyy \\ +aby-byy \end{array}\right.$$

Taking away the Superfluous Terms which deſtroy themſelves, and dividing he reſt by y, one ſhall have

$$2cx+2bx = ac-ab+cy+by.$$

herefore $x = \frac{ac-ab}{2c+2b} + \frac{1}{2}y.$

and $x-y = \frac{ac-ab}{2c+2b} - \frac{1}{2}y.$

It is for this reaſon if one make the Sin of the Angle of Incidence A V $=\frac{ac-ab}{2c+2b}+$ and the Sine A $u=\frac{ac-ab}{2c+2b}$ ---- $\frac{1}{2}y$ one ſhal have the Sines of the Angles A B C an A B *c*, which the Sails D C, *d c* make wit the Wind, which will be in ſituations equally advantageous; and as the differenc of the Sines *y* is undetermined, one ſhall find an infinite of Points C *c*, which taken two and two will give ſituations of Sai equally advantageous, that is to ſay, if fo example, you take the Point C, you wi have another as *c*, equally advantageous Whence it is evident, that the more you encreaſe the value of *y*, the more the Point will be diſtant from the Point *c*, and th more you diminiſh it, the more theſe tw Points will approach. If you ſuppoſe *y* equal to nothing, the Points C and *c* wi become one and the ſame Point, and yo will have $X=\frac{ac-ab}{2c+2b}$ which will be the value of A V, or the Sine of the Angle of Incidence of the Wind upon the Sail. This Poin C will determine the moſt advantageou ſituation of the Sail C D, ſince you cann take any other Point, as *c*, from whenc making the conſtruction, as has been don the Ratio of A V to A *u*, would not b greater, than the Ratio of *n p*, to N

Chap. IV. Fo

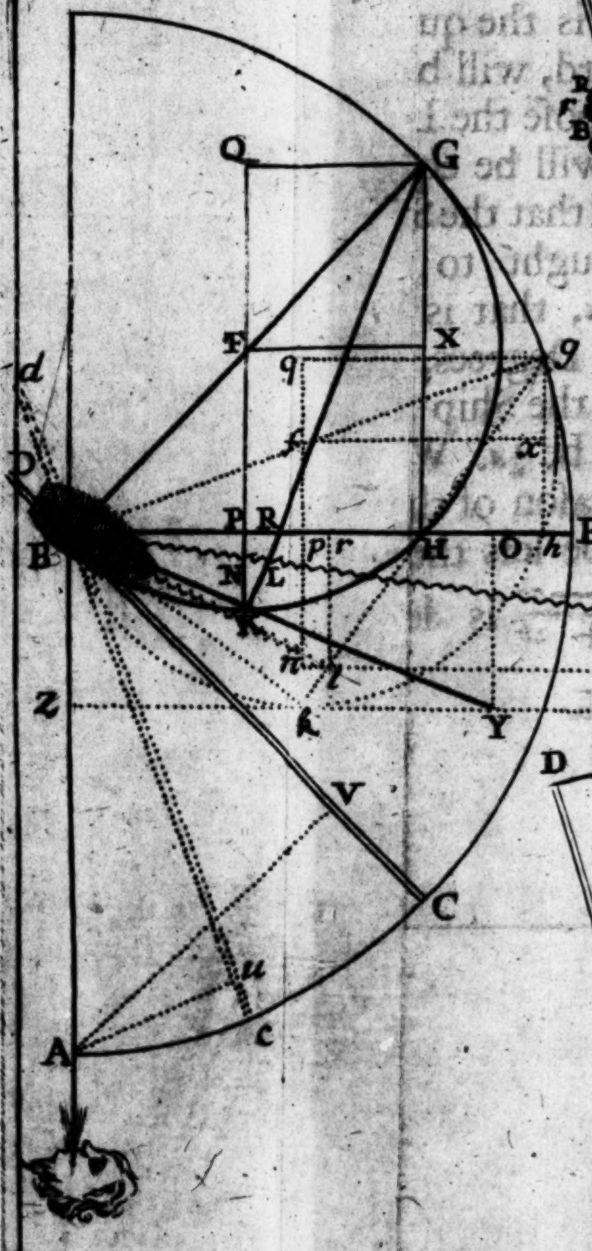
For in ſubſtituting in the Equation $\frac{ac - ab}{2c + 2b}$ n the Place of x, the product of the Extreams will be greater than that of the means, or, $acx - cxx - abx - bxx$, will be a greater quantity than $acx - cxx$ &c. which is the other Member of the Equation. There will therefore be a greater Ratio of the firſt Term to the ſecond, than of the third to the fourth, or, that which s the ſame thing, there will be a greater Ratio of A V, to A u, than of & △, to L R, or that of B &, to B L. The value of $x = \frac{ac - ab}{2c + 2b}$, makes known that he Relation of c to b may be ſuch, that he value of x may be Negative, or equal o nothing; that is to ſay, that the difficulty which the Ship finds to divide the Water with her Stem foremoſt, might be ſo great, in relation to that which it might have to divide it with her Side; that the Ship, inſtead of gaining to Windward, ſhould only looſe, or that it ſhould continually follow a Courſe perpendicular to the Wind. But to render $x = o$, the difference of c to b, muſt be alſo equal to nothing, that is to ſay, that the difficulty which the Ship finds to move through the Water End-ways, ſhould be equal to that ſhe finds to move through the Water Side-

ways,

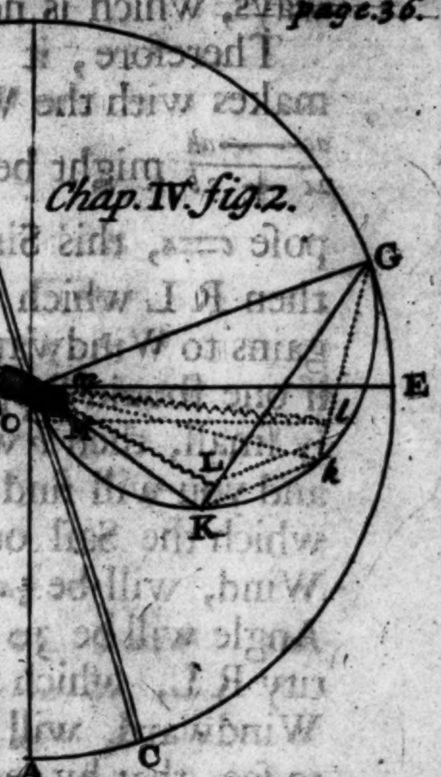
ways, which is not found in any Veſſ
Therefore, it muſt be that the S
makes with the Wind, an Angle where
$\frac{ac-ab}{2c+2b}$ might be the Sine: or if one ſu
poſe $c=a$, this Sine will be $\frac{aa-ab}{2a+2b}$, a
then R L which is the quantity the Sh
gains to Windward, will be $\frac{1}{4}a-\frac{1}{4}b$. Whi
if one ſhould ſuppoſe the Lee-way infini
ly ſmall, then b will be equal to nothin
and you will find that the Sine of the An
which the Sail ought to make with t
Wind, will be $\frac{1}{2}a$, that is to ſay, that th
Angle will be 30 Degrees, and the qua
tity R L, which the Ship will gain to t
Windward, will be $\frac{1}{4}a$. Whence it is ea
to ſee, that by reaſon of the Lee-way, t
Angle ought to be leſs then 30 Degree
becauſe that $\frac{aa-ab}{2a+2b}$ is leſs then $\frac{1}{2}a$ b
the quantity $\frac{ab}{a+b}$

page.36.

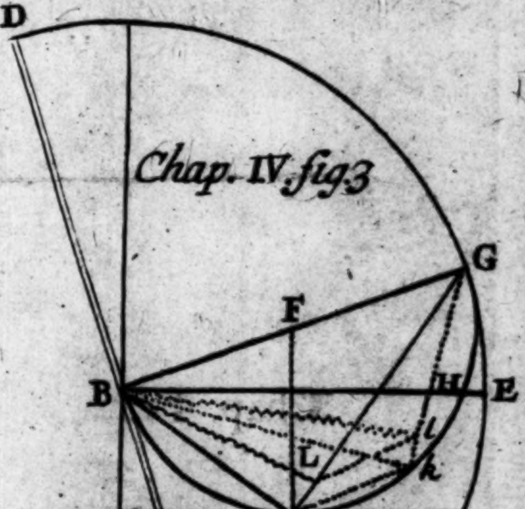
Chap. IV. fig. 4



Chap. IV. fig. 2.



Chap. IV. fig 3



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CHAP. V.

Of the manner of Determining the Different Lee-ways, which depends on the Different Situations of the Ships Stem, in relation to the Sail.

ARTICLE I.

IN the firſt Figure, let A B be the Wind, C D a Situation of the Sail, B G perpendicular to C D and the Diameter of the Semicircle B K G, B K the Situation of the Ship: Taking another Situation of the Ship, as B *k*, let be drawn G *k*, and let B G, be to B I, as the reſiſtance which the Ship finds to move through the Water Sideways, to that it finds to move through the Water Endways, and upon the Diameter I G, deſcribe the Semicircle I L G, which will cut the Lines K G and *k* G, in the Points L and *l*, and let be drawn the Lines B L and B *l*.

All the Angles as B K G and B *k* G, are right, becauſe they are in the Semicircle. All the Lines as K G and *k* G, are cut in ſuch manner by the Semicircle I L G, that K G is to K L, and *k* G is to *k l*, as B G, is to B I; becauſe that drawing the ſtrait Lines from the Point I, to the Points L and *l*, theſe Lines will be parallel to the Lines B K and B *k*, and the Lines B G, K G, and *k* G, will be cut in the ſame proportion in the Points I, L, and *l*. All theſe Lines are therefore cut in ſuch proportion, that all the Line is to its part contained between the two Semicircles, as the reſiſtance which the Ship finds to go through the Water Sideways, is to that ſhe finds to go through it Endways.

So by the firſt Article of the ſecond Chapter, when the Ship ſhall be in the Situation B K, the Line B L ſhall be the Line of her true Courſe, and ſhe will go to the Point L, in the time ſhe would have been at the Point G, if ſhe ſhould ſplit the Water on all ſides with the ſame facility ſhe does with her Stem; and the Angle B K L will be the Angle of the Drift or Leeway. When the Ship ſhall be in the Situation B *k*, ſhe will go to the Points *l* alſo in the ſame time, and the Angle *k* B *l* will be the Angle of her Drift, or Leeway. It will be the ſame in all other Situations of the Ship.

ARTICLE II.

So that the ſituation C D of a Sail being given, and the Conſtruction of the Figure made as uſual, it will be eaſie to determine the Line of the Ships way, in whatſoever ſituation you put the Ship, in relation to the Sail. For you need only to draw the Line of the ſituation of the Ship as B K, which cuts the Semicircle B K G in the Point K, and from the Point K, draw K G, which cuts the Semicircle I L G at the Point L; then the Line B L will be the true Courſe of the Ship. If it is the Line that you deſire the Ship ſhould run, which is given in relation to the Sail, as the Line B L, which cuts the little Semicircle in the Point L; you muſt draw the Line G K by the Points G and L, and from K draw the Line B K; this Line will be the ſituation in which you ought to put the Ship, for to make her run in the Line B L.

ARTICLE III.

If, in the ſecond Figure, you draw from the Point B, the Line B L Tangent to the Semicircle I L G, the Line G K by the Points G and L, and the Line B K; This laſt Line will be the ſituation in which you muſt put the Ship, to the end that the Courſe B L may make with the Sail C D, the ſmalleſt Angle that is poſſible. The Angle C B K, that the ſituation of the Ship makes with that of the Sail, will be alſo the leaſt that can happen; for if you ſhould put the Ship in the ſituation B *k*, B *l* will be the Line of the true Courſe, and the Angle C B *l*, which this Line would make with the Sail C D, would be greater than the Angle C B L. One may eaſily ſee that it will be the ſame with all other Situations of the Ship.

ARTICLE IV.

The little Semicircle I L G, determines the relation which is, between the lengths of the Lines run through in equal times by a Ship in all her different Situations. For it hath been made appear, that if B L were the Courſe of the Ship, the Ship would arrive at the Point L, in the ſame time ſhe would have been at the Point *l*, if her Courſe had been in B *l*; and in the time ſhe would have been at H, if her Courſe had been in B H; and it will be the ſame in all other Courſes, ſeeing the Ship would arrive at all the Points of the Semicircle I L G, in the ſame time that it

would

would run to the point G, if it moved through the Water on all ſides with the ſame facility it does with the Stem foremoſt.

CHAP. VI.

Of the moſt advantageous Situation of the Sail, and of the Ship, in relation to the Wind, and the Courſe you would Steer.

ARTICLE I.

LET, in the firſt Figure, A B be the Line of the Wind, draw the Line B M from B, the place the Ship is in, to M the place ſhe would go to; in whatever Situation you put the Sail in regard to the Wind, you muſt, by the Method of the ſecond Article of the Fifth Chapter, diſpoſe the Ship in ſuch manner that ſhe make her Way in the Line B M, which makes the Angle A B M with the Line which repreſents the Wind.

DEMONSTRATION.

Let, C D be ſuch Situation of a Sail as you deſire, B G perpendicular upon C D, let B G, be to B I, as the reſiſtance the Ship finds to move through the Water ſideways, is to the Reſiſtance ſhe finds to move through it endways, upon I G deſcribe the Semicircle I L G, which will cut the Line of the Courſe B M, in the Point L. If the Line B M be not the moſt convenient to go to the Point M, of neceſſity there muſt be ſome other Courſe as B *l*; the Ship after having followed this Line ſome time, as far as the Point M *l*, it ſhould go from the Point *l* to the Point M in the Line *l* M, but it would take more time to run thro' theſe two Lines, than if ſhe had always moved in B M. For if one ſhould draw B *l*, parallel to *l* M, and *l* L which prolonged cuts *l* M in the Point P, the Triangles L M P, L B *l*, are alike; So that P M is to L M as *l* B is to B L. The Ship will move upon *l* M as upon B *l*, becauſe theſe two Lines make the ſame Angle with the Wind. The Ship by the Fourth Article of the Fifth Chapter will run through B *l*, B L, and B *l* in an equal time, it will therefore run through P M in the ſame time as L M, and all the Line BM, in the ſame time as the two Lines B*l* and PM together. But there is wanting part of the Way *l*P, that ſhe wants of running over ſo ſoon the Lines B*l* and *l*M, as the Line BM. Therefore the Line BM will be the moſt convenient Courſe from B to M; for taking any other Point Windward, or to Leeward of the Point L, one may reaſon in regard to this Point, as has been done in regard to the Point *l*.

ARTICLE II.

So that, if a Ship ſhould be at the Point B, and the Wind going according to the Determination AB, and that the Line BM was drawn from the place where the Ship is, to the place where ſhe would go; in whatſoever Situation you put the Sail, as in CD, you muſt (by the Method of the Second Article of the Fifth Chapter,) diſpoſe the Ship's Head in ſuch manner, that the Ship's true Courſe may be in the Line BM, which makes with the Line of the Wind the Angle ABM.

ARTICLE III.

Determining then the moſt advantageous ſituation of the Sail, in relation to the

Wind, and to the Courſe which is propoſed to be made, all will be determined, ſeeing the ſituation of the Ship depends neceſſarily on that of the Sail.

Suppoſing that in the Second Figure, A B were the Line of the Wind, B E the Courſe ſhe muſt hold, the Matter is to determine the moſt advantageous ſituation of the Sail, in relation to the Wind and the Courſe. And to that end let C D be one ſituation of the Sail; B G perpendicular to C D; let B G be to B I, as the reſiſtance that the Ship finds to move through the Water ſideways, is to the reſiſtance ſhe finds to move through the Water endways, upon I G deſcribe the Semicircle I L G, which is ſuppoſed to cut the Line of the Courſe B E, in N and L; if the Ship be poſited according to the Circumſtances marked in the Second Article of the Fifth Chapter, ſhe will make her way B L in the courſe B E, in the ſame time ſhe would have run over B G, if ſhe ſhould ſplit the Water every way alike.

Likewiſe, if you ſuppoſe *c d* another ſituation of the Sail; B *g* perpendicular to the Sail *c d*, and equal to B G, and the Semicircle *i l g* equal to the foregoing, which cuts alſo the courſe B E in *l*, the Ship by the ſame Reaſon will make her way B *l*, in the ſame time that ſhe would have run over B *g*, if ſhe ſhould ſplit the Water on all ſides alike; therefore, if the Ship were puſhed with the ſame force, in theſe two ſituations of the Sail, ſhe would arrive in L when the Sail is in the ſituation C D, in the like time ſhe would arrive in *l*, when the Sail is in the ſituation *c d*. So that the Ship would advance leſs when the Sail ſhall be in the ſituation C D, than when it is in the ſituation *c d*, in the proportion that B L is leſs than B *l*; and to the end ſhe may advance ſo much when the Sail is in C D, as when it is in *c d*, you muſt augment the ſwiftneſs of the Ship in the proportion that B *l* is greater than B L; but becauſe that the ſwiftneſs of the Ship's Motion augments in proportion to the Sine of the Angle of Incidence of the Wind on the Sail, it muſt be that the Sine A V of the Angle A B C of the Wind, upon the Sail when it is in the ſituation C D, ſhou'd be to the Sine A *u* of the Angle A B *c*, that the Wind makes with the Sail when it is in the ſituation *c d*, as the way B *l* is to the way B L; and if the Sine A V has a greater Ratio to the Sine A *u*, than B *l* to B L, the Ship will advance more when the Sail ſhall be ſituated in C D, than when in *c d*. On the contrary, the Ship will advance leſs when the Sine A V ſhall have a leſs relation to the Sine A *u*, than B *l* to B L.

What remains therefore, is to find a Sine, as A V, which has a greater Ratio to any other Sine A*u*, than B*l* to B L, whereby you will find out the moſt advantageous ſituation of the Sail, and for that purpoſe, you muſt by the Method of the Fourth Chapter, ſuppoſe the Sine A V=*x*, and ſuch another Sine that you deſire, as A *u*=*x*-*y*, ſo the difference of theſe Sines may be *y*, and B G, or B*g*=*a*: But as the value of *x*, which is ſought, gives an Equation of a very compoſed Degree, and by conſequence, unuſeful for Practice, it will be more to the purpoſe to make uſe of the Mecanic Method of the Eighth Chapter.

CHAP. VII.

Of the Angle which the Rudder ought to make with the Keel of the Ship, for to ſtay, or bear up the ſooneſt that is poſſible.

LET the Line A B repreſent the Keel of the Ship, B D one ſituation of the Rudder, B C the Rudder prolonged, or the Tiller of the Rudder, B the Point of the Stern-Poſt, on which the Rudder turns. From this Point B, as Center, let be deſcribed a Circle, as D G E, draw B E perpendicular to A B, B G perpendicular to C D, and G H perpendicular to B E. Take another ſituation of the Rudder, as B *d* prolonged to *c*, and in the ſame Circumſtances draw B *g*, and *g h*.

If the Ship moves forward according to the Line B A, the Angles A B C, and A B *c*, equal to the Angles G B E, and *g* B E, will be the Angles of Incidence, of the Particles of Water againſt the Rudder, in the two ſituations C D and *c d*; and the Lines G H, and *g h* will be the Sines of theſe Angles. If the Lines B G and B *g* which are equal, ſhou'd expreſs the force with which the Rudder is puſhed according to theſe ſame Lines in the two ſituations of the Rudder, B H wou'd expreſs that with which it wou'd be puſhed according to B E, when the Rudder was in the ſituation of B D, and B *b* wou'd alſo expreſs that with which it wou'd be puſhed according to B E when it was in the ſituation B *d*; ſo that the Rudder wou'd be more puſhed according to B E when it was in the ſituation B *d*, than in that of B D in the ſame proportion that B *b* is to B H.

Therefore, to the end it may be puſhed equally according to B E in theſe two Situations, it behoveth, that the force with which it is puſhed according to B G, when it is in the ſituation B D, ſhou'd be greater than that with which it is puſhed according to B *g* when it is in the ſituation B *d*, in the ſame proportion that B *b* is to B H. But likewiſe the Rudder is more puſhed in the ſituation C D, than in *c d*, in the ſame proportion that the ſquare of the Sine of the Angle A B C, is greater than the ſquare of the Sine of the Angle A B *c*. Therefore, if the ſquare of the Angle A B C, that is to ſay, the ſquare of G H, is to the ſquare of the Angle A B *c*, that is to ſay, to the ſquare of *g h*, as B *b* is to B H, the Rudder will be equally puſhed according to B E in theſe two ſituations of the Rudder; and conſequently they will be equally advantageous. But if the Ratio of the Squares is greater than that of the Lines the ſituation CD will be more advantageous than the ſituation *c d*; if the Ratio of the Lines is greater, the ſituation *c d* will be the moſt advantageous.

It muſt be remarked, that one cannot rigorouſly ſuppoſe, that the impulſion of the Water againſt the Rudder, is made in the Point B; for this Impulſion cannot be united but in the Center of impulſion of the Rudder; that is to ſay, pretty near its middle. So that the force which obliges the Ship to turn, does not determine it to move according to the Line BE perpendicular to the Keel, but according to a perpendicular to a Line, which might be drawn from the Center of the Movement of the Ship to the Center of Impulſion of the Rudder. This Line is very near the ſame as the Keel of the Ship, becauſe the half of the Rudder's breadth is inſenſible, in regard to its diſtance from the Center of Movement of the Ship; by conſequence a perpendicular to this Line, is ſenſibly the ſame as the Line B E of which we have ſpoken.

Inſomuch, that if there was a Point, as G, from whom making a Conſtruction,

as

as ſhall be ſhown, there wou'd be always a greater Ratio of the Square of G H, to the Square of any other Sine as *g h*, than there wou'd be of B *h*, to B H; the Ship wou'd govern quicker when the Water ſhou'd make with the Rudder an Angle of Incidence equal to the Angle G B E; or that the Rudder ſhou'd make with the Keel the Angle D B A, than when it ſhou'd make with the Keel any other Angle whatſoever.

For to find this Point by the Method of the Fourth Article of the 4*th* Chapter.

Let B G $= a$.

B H $= x$.

$y =$ H *h*, or to the Difference betwix B H, and B *h*.

Then B *h* $= x + y$.

G H $= \sqrt{aa - xx}$.

$g h = \sqrt{aa - xx - 2xy - yy}$.

Suppoſing the Square of G H ſhou'd be to the Square of *g h*, as B *h* is to B H; one ſhou'd have,

$$aa - xx . aa - xx - 2xy - yy :: x + y . x$$

Which will give the Equation,

$$aax - x^3 = \left\{ \begin{array}{l} aax - x^3 - 3xxy. \\ 3xyy + aay - y^3 \end{array} \right.$$

Taking away the Terms which deſtroy themſelves, and you will have by dividing by *y*

$$aa - 3xx - 3xy - yy = 0.$$

Making $y = 0$, you will have,

$$aa - 3xx = 0.$$

$$x = \sqrt{\tfrac{1}{3}aa}.$$

and $GH = \sqrt{\tfrac{2}{3}aa}$.

inſomuch, that if you make $BH = \sqrt{\tfrac{1}{3}aa}$, or $GH = \sqrt{\tfrac{2}{3}aa}$, you wou'd have the Point G, in ſuch manner that there wou'd always be a greater Ratio, of the Square of G H, to the Square of gh, than of B h, to B H. For ſubſtituting in the firſt Equation, $\sqrt{\tfrac{1}{3}aa}$ in the place of x, the Product of the Extreams $aax - x^3$ will be greater than the Product of the Means which will compoſe the other Member of the Equation.

Thus drawing from the Point G, the Line G B perpendicular to the Rudder at the Point B, the Angle A B D will be the Angle which it behoves the Rudder to make with the Keel, or the Angle A B C that of the Tiller with the Keel. The Sine of the Angle A B C, will be equal to $\sqrt{\tfrac{2}{3}aa}$; that is to ſay, That the Tiller of the Rudder make with the Keel an Angle pretty near 55 Degrees.

To the end, that the Rudder makes preciſely this Angle with the Keel, you muſt put a Cleat on the Sweep in the Gun-Room, and to diſpoſe it in ſuch manner, that the Arch contained betwixt the Keel and Cleat, may be of the Number of Degrees ſpoken of, the Tiller of the Rudder ought always to be thus ſtopp'd by this Mark, for if it paſſes it, it will hurt it more than help it.

CHAP. VIII.

Of the manner to determine Mechanically the moſt advantageous Situation of the Sails and the Ships Head, as well to gain the Wind, as to make any other Courſe you deſire, or to give Chaſe to a Veſſel.

ARTICLE I.

LET ABR in the firſt Figure, repreſent the Line of the Wind, and let BR be divided into two equally at the Point M, and BM in the Point N. Let MN be divided in a hundred equal Parts, which will repreſent the Relation there is betwixt the Reſiſtance the Ship finds to move through the Water ſideways, and that which ſhe finds to move through it endways, by ſuppoſing that this Relation is as a hundred to a certain Number; let

B S be the half of M N, and by the Points B & S, draw the Lines B Y, S X, perpendiculars to the Line of the Wind A B, betwixt theſe two Lines draw ſeveral Parallels, the one near the other, the Line S X will be the Windward-moſt of thoſe which the Ship can attain in the Circumſtances noted at the end of the Fourth Chapter, from the Point N as Center, and with the Interval N B, deſcribe the little Circle B H M. Likewiſe from the Point M as Center, and with the Interval M B, deſcribe the great Circle B F R, whoſe Circumference let be divided in 180, or the half Circumference in 90 equal Parts for to mark the Angles which the Sail ought to make with the Wind.

From the Point B, at each of theſe Diviſions of the grand Circle, draw the Lines B F, of whom we have repreſented only the Parts H F, theſe Chords B F will repreſent the perpendicular Lines to the Sail in all ſorts of Situations, and the Proportion of the Swiftneſſes of the Ship, ſuppoſing the Keel always perpendicular to the Sail; for if you ſuppoſe the Sail ſituated in D C, and the Line B A equal to B R. Let A V be the Sine of the Angle of Incidence A B C of the Wind upon Sail, and the Chord B F 50 perpendicular to the Sail B C, if the Keel of the Ship is according to BF 50, that is to ſay, that the Head be turned towards the Point F 50, the Ship will go towards the Point F 50, by the Ninth Article of the Firſt Chapter. Moreover, by the Fourteenth Article of the Firſt Chapter, the ſwiftneſs of the Ship, when the Sail is in BY perpendicular to the Wind, and her Head turned towards R, is to its Swiftneſs when the Sail is in B C, and her Head towards F 50, as the Sine of the Angle of Incidence A B Y, is to the Sine of the Angle A B C; that is to ſay as A B to A V, or as B R is to B F 50; becauſe that the two Triangles A B V, and B R F 50 are equal: Therefore, if B R marks the way which the Ship makes in any certain time when the Sail is perpendicular to the Wind, and the Head is turned towards R, B F 50 ſhall repreſent the way of the Ship, when the Sail is in B C perpendicular to B F 50, and that the Head regards the Point F 50; it will be the ſame with all the Chords B F drawn from the Point B to the Circumference of the great Circle.

Chap. VIII.

ARTICLE II.

For the uſage of this Figure, it is neceſſary to know (by the Method of the Third Article of the Second Chapter) the Proportion there is betwixt the Reſiſtance the Ship finds to move through the Water ſideways, to that ſhe finds to move through the Water endways, and this Proportion ought to be as 100 to ſome Number, ſuppoſe, for Example, to 10. You muſt take the Point P at the Diviſion 10, from which as a Center and with the Interval P B, deſcribe the prickt Circle B G Q, which will contain all the Centers of the Semicircles which ought to determine the quantity of the way of a Ship, according to the Method of the Fourth Article of the Fifth Chapter. For making Q K equal to Q R, B K will be quadruple of N P, becauſe that B Q is double of B P, and B M double of B N; therefore the remainder of M Q will be double of the remainder N P. Moreover B R is double of M R, and K R double of Q R; therefore the remainer B K is double the remainer M Q, and by conſequence quadruple of P N. From whence it follows, that B R is to B K, as N M the fourth part of B R, is to N P the fourth part of B K, that is to ſay, as the reſiſtance which the Ship finds to move through the Water Side-foremoſt, is to that which ſhe finds to move through the Water End-foremoſt. Upon BK deſcribe the little Circle BIK, which cuts a Chord BF in I, this Chord BF will be cut in the ſame proportion as the Diameter BR is; for drawing the Lines RF, QG, and KI, theſe Lines will be perpendiculars to BF, and conſequently Parallels one to the other. Therefore as KR is cut equally in Q, FI will be ſo likewiſe in G, and BF will alſo be to BI, as the Reſiſtance the Ship finds to move ſideways is to that ſhe finds to move endways. From a Point G 50 as Center, and with the Interval G 50 F 50, deſcribe the Semicircle F 50, I 50. By the ſame 4th Article of the Fifth Chapter, the Sail being in BC in whatſoever Situation you put the Keel, the Ship will arrive in an equal time to all the Points of the Circumference I 50 F 50. Therefore the Semicircle I 50 F 50 determines the quantity of the way of a Ship when the Sail is perpendicular to BF 50, and conſequently the Point G 50 is the Center of the Circle which determines the quantity of the way in any Courſe which may be. It is the ſame of all the other Points G of the Circumference BGQ, from whence it follows, that this Circumference contains all the

Centers of Circles which determine the quantity of the way of a Ship, whoſe reſiſtance to move through the Water ſideways, is to that ſhe finds to move through the Water endways, as MN is to NP, or, as 100 is to 10.

ARTICLE III.

Now for to find the moſt advantageous Situation of a Sail, for to keep a propoſed Courſe as BE, take at diſcretion a Point G 40 in the middle Circumference on one of the Chords, from whence as Center, and with the Interval G 40, F 40 of this Chord, let there be deſcribed an Arch which ſhall touch the Line BE of the Courſe in a Point, or ſhall cut it in two Points, of which let 40 be the moſt diſtant; let there be taken another Point G 50 in the middle Circumference, and let there be found in the ſame Circumſtances the Interſection 50; let this Operation be reiterated, until you have found with the ſame Circumſtances in the Line BE, the Interſection which is the fartheſt diſtant from B, ſuppoſe that it is 50 which has been found by the Interſection of an Arch, of which G 50 is the Center; I ſay, that the Arch BF 50 will mark the Number of Degrees which the Angle of the Sail with the Wind ought to make, to the end it may be in the moſt advantageous Situation for to hold the Courſe B E, ſuppoſing the Keel is diſpoſed, as we have ſaid in the Third Article of the Sixth Chapter.

DEMONSTRATION.

I now come to ſhew that the Ship wou'd arrive in the ſame time to all the Points of the Circumference I 50 G 50, when the Sail is according to B C perpendicular to B F 50, and by conſequence the Ship arrives at the Point 50 (when the Sail is diſpoſed with the Circumſtances marked in the Third Article of the Sixth Chapter) in the ſame time ſhe arrives at the Point F 50, when the Head is turned towards F 50, that is to ſay, in the ſame time that ſhe wou'd arrive in R, if the Sail was in B Y, and the Head turned towards R.

And if one take all other Situations of the Sail B *e*, it will be leſs advantageous to hold the Courſe B E, for drawing the perpendicular B F 40, which rencounters the middle Circle in G 40, from the Point G 40, and with the Interval G 40, F 40, deſcribe a Circle which cuts the Line B E in 40, the Ship will arrive at the Point 40 in the ſame time that it wou'd arrive at the Point R with Circumſtances like the preceding; and by conſequence ſhe will arrive at the

Point 40, when the Sail is ſituate in B : in the ſame time ſhe wou'd arrive in 50, when the Sail is in B C, with the Circumſtances noted in the Firſt Article of the Fifth Chapter. But by Conſtruction, the Point 50 is further off from the Point B than all other Point 40 ; and by conſequence the Ship will advance more when the Sail is in B C, than when in all other ſituation B C.

As the Circumference of the great Circle has been only divided in 180 parts, one of theſe parts will be two Degrees : So the Angle B R F 50 having for Meaſure the Moeity of the Arch B F 50 will have for Meaſure the number of parts noted in the Arch B F 50, in taking them for Degrees, that is to ſay, this Angle will be 50 Degrees ; but the Chord B F 50 having been ſuppoſed perpendicular to the Sail B C, and being the ſame alſo to the Line R F 50, it follows, that R F 50 is parallel to the Sail C B, and that the Angle A B C of Incidence of the Wind upon the Sail, is equal to the Angle B R F 50 ; and by conſequence, that it hath alſo for Meaſure, the number of the parts of the Arch B F 50 taken for the Degrees.

ARTICLE IV.

And if you wou'd have the moſt advanvantageous Situation of the Sail to gain to Windward, draw at diſcretion a Chord BF 24, and deſcribe a Semicircle F 24 L *i* in the ſame Circumſtances as above, which will touch one of the Parallels to BY in the Point L, with the ſame Circumſtances deſcribe other Semicircles, and take the Chord of that which touches the Parallel which is moſt to Windward, or which is neareſt to S X. Suppoſe that it is the Semicircle F 24, L *i* formed on the Chord B F 24, I ſay that the Arch B F 24 ſhews the number of Degrees which the Sail ought to make with the Line of the Wind, to the end the Ship, may go to Windward the moſt that is poſſible. The Demonſtration is the ſame as the preceding.

ARTICLE V.

To have a Figure which ſhall at one view mark the Situation of the Sail of a Ship whoſe reſiſtance to move through the Water ſideways, is to her reſiſtance endways in a given Relation, as of 100 to 10. You muſt make the Second Figure in the manner following.

Draw, as in the Firſt Figure, the Line BR, and the perpendicular BY, divide BR equally in two at the Point M, and BM in N, let M N be to N P as 100 to

10, divide P B equally in two at the Point *p*, from the Points B, *p*, P, M as Centers, deſcribe the Circles R Z, B F R, B G Q, and B T P. Divide the Arch R Z in degrees for to ſhew the Angles of the Given Courſes with the Wind.

Divide likewiſe the Semicircle B F R in 90 equal Parts, for to find the degrees which mark the value of the Angle which the Sail ought to make with the Wind. It will ſuffice to mark every 5 degrees. From the Point B to each diviſion of the Semicircle B F R draw the Chords as B F, which will cut in like Parts the Semicircles B G Q, and B T P.

Take one of the Chords, as B *f* which cuts the other Semicircles in G and T, by the Points P & T draw a Line which will cut BZ in Y, from whence, as a Center, and with the Interval Y B, deſcribe the Arch B G D which will cut the middle Circle in G. From the Point G as Center, and the Interval G F deſcribe a little Arch which will cut the preceding Arch in D.

Take likewiſe the other Chords, and following the ſame Method, deſcribe little Arches, which being joined the one to the ther, will form the Curve B D R, which will be ſo much the more exact by how many more little parts the Semicircle B F R ſhall be divided into. Moreover, thi Curve will be divided by the Arch B G D, and by the like Arches in parts which wil represent the Degrees which ſhew the value of the Angle which the Sail ought t make with the Wind, to the end they may be in the moſt advantageous Situation for to hold a given Courſe, or to gai to Windward.

ARTICLE VI.

For the firſt uſage of this Figure, le the Courſe B E be propoſed, which makes with the Line of the Wind a given Angle, it remains to find the moſt advantageous Situation of the Sail of a Ship, which find the reſiſtance of moving through the Water ſideways to that of moving throug endways, as 100 to 10, as we have ſuppoſed in the Conſtruction of the Figure.

Draw the Line of the Courſe B E, which makes with the Line of the Wind B R the given Angle A B E, this Line B E, cut the Curve Line in a Point, as 60, which ſhews that the moſt advantageous Situation of the Sail for to hold the Courſe B E, is when it makes with the Wind an Angle of 60 Degrees.

DEMONSTRATION.

In the Third Figure let be deſcribed the Circle B G D X, which ſerves to find the Point 60 of the Curve, that Circle cuts the middle Circle in G, by the Point G draw the Chord B F, draw alſo R F, and B C perpendicular to B E, and laſtly, from the Point G, and with the Interval G F, let be deſcribed the Semicircle F D I, which will paſs by the Point 60, according to the Conſtruction.

It remains now to ſhew, Firſt, That the Angle A B C is Sixty Degrees. Secondly, That the Sail being in B C, will make the Ship to run in the Courſe B E the quantity B D, the Keel being diſpoſed according to the Method of the Fifth Chapter. Thirdly, That the Situation of the Sail B C is the moſt advantageous of all.

1. By the Conſtruction of the Figure the Arch B G D, which gave the Point 60, has been determined by the Chord B G F, which cuts the Semicircle B F R at the Point 60, in ſuch manner, that the Angle B R F, which has for Meaſure the half of the Arch B F, is 60 Degrees; but the Lines R F, and B C being perpendiculars to the Chord B F, they are parallel one to the other; therefore the Angle A B C is equal to the Angle B R F, and

by conſequence the Angle A B C of the Sail with the Wind contains 60 Degrees.

2. If the Sail is in the Situation B C, and the Keel diſpoſed according to the Method of the 2d. Article of the 5th Chapter, to go in the Courſe B E, the Ship will go to the Point D in the ſame time ſhe wou'd have been at R, if the Sail had been B Z, and the Head of the Ship turned towards R, as does appear by what has been done in the Fourth Article.

3. In fine, If you take ſuch other Situation of the Sail B *c*, as you pleaſe, it will be leſs advantageous (to keep in the Courſe B E) than the Situation B C.

For, let be drawn the Chord B *f* perpendicular to B *c*, which cuts the middle Circle in *g*; by the Points *g* G draw *g* V, which cuts the Circle B G D in *n*; draw G Y which cuts the ſame Circle in X; draw alſo the Lines B X, D X. Divide the Arch *n* X in two equally at *m*; draw by B and *m* the Line B V, which will rencounter *g* V in V; draw alſo V *s*, by the Points V D. In fine, draw *g* S parallel to G D which rencounters V *s* in *s*, and *g h* parallel to G B which rencounters V B in *h*.

In the Circle G B X, the Line G X is the Diameter, therefore the Angles G D X, and G B X are right, and by conſequence

G D, and its Parallel *g* S are Perpendiculars to S X, and G B to B X.

The Line Y B touches the middle Semicircle B G Q in the Point B, therefore its Equal Y G will touch it alſo at the Point G.

The Angle *g* B G is equal to the Angle X G *n*, for the Angle *g* B G has its Top B, in the Circumference of the middle Circle B G Q, and is upheld upon the Arch *g* G, and the Angle X G *n*, or rather its oppoſite *g* G *x*, at the top of it is formed by the Chord of the ſame Arch G *g*, and by the Tangent G *x*.

The Angle *m* B G is equal to the Angle *b* B *g*, for the Angle C B G is equal to the Angle *c* B *g*, becauſe they are right, the Arch X *m* being equal to the Arch *m n*, the Angle *m* B *n*, or its oppoſite *b* B *d*, is equal to the Angle *m* B X; therefore if you take away the former, the Remainers *m* B G, *b* B *f*, will be equal.

The Line *g b* is equal to *g* B, becauſe that the Line *g b* is parallel to G B; therefore the Angle *g b* B is equal to the Angle G B *m*, or to its Equal *g* B *b*; therefore the Triangle *b g* B is Iſoſceles, and by conſequence *g b* is equal to *g* B.

The Line *g s* is a part of *g* S, for the Points *m* and *n* being towards the ſame ſide in regard to S X, the Point V, which is their common Interſection, will alſo be towards the ſame ſide, as well as the Part V D of the Line V *s*, therefore the other part D *s* will be of the other ſide of the ſame Line, and will cut off the Part S *s* of the Line *g* S, and conſequently the Line *g s* will be a Part, or will be leſs than *g* S.

The Line *g s* is equal to the Line *g f*, for the Lines *b g*, B G being Parallels as well as *g s* and G D; It follows that *b g*, or its equal B *g*, is to B G as *g* V is to G V. But as *g* V is to G V ſo is *g s* to G D. Therefore B *g* is to B G as *g s* is to G D. But the middle Circle Q G B cuts proportionally the Chords B *f* B F; thence it follows, B *g* is to B G, as *g f* is to G F; but by conſtruction the Line G F is equal to G D, becauſe they are Radius's of the ſame Circle, therefore *g s* is equal to *g f*.

In fine, For to prove that the Situation of the Sail B *t* is leſs advantageous than the Situation B C; After having drawn (as we have ſaid) the perpendicular Chord B *f*, which is cut by the middle Circle at the Point *g*, from whence as Center with the Interval *g f*, deſcribe a Circle which will cut the Line of the Courſe B E in a Point more near to B, for the Circumference of the Circle will paſs by the Point S, ſeeing we have ſhewed that *g f* and *g s* are equal. Moreover, *g* S being perpendicular to

S D it will be leſs than *g* D, and conſequently the Circumference of the Circle *f s* will cut the Line B E in a Point which is nearer to B, as you ſee at D. Therefore the Situation of the Sail B *c* is leſs advantageous than the Situation B C.

And as one can prove the ſame thing of all other Situations, it follows, that the Situation of the Sail B, which makes with the Wind an Angle of ſixty Degrees, is the moſt advantageous to hold the Courſe B E.

ARTICLE VII.

The Conſtruction of the Curve of the Sixth Article, makes appear the Proportions of the Way which a Ship makes on any Courſe whatſoever, having the Sails and Keel diſpoſed after the moſt advantageouſeſt manner, for to hold each of theſe Courſes: For if in the Courſe B E the Ship makes the Way B D 60 in the ſame time ſhe makes the Way B 70 in the Courſe B *e*, the Sails and the Keel being diſpoſed as has been ſaid, the Ways which the Ship will make in each of theſe Courſes will be in the ſame Ratio that B 60 is to B 70.

It is true that the Ship advances more in following the Courſe B *e* than in following the Courſe B E: But it alſo falls more to Leeward in proportion of the Perpendicular drawn from 70 to B Z, and the Perpendicular drawn from 60 upon the ſame Line B Z.

ARTICLE VIII.

One may eaſily ſee from all this, what ought to be obſerved when one give chaſe to a Veſſel which is to Leeward. For if on one Side to make more Way you go more large, that is to ſay, if you make a greater Angle with the Line of the Wind and Courſe; you ought to take care not to fall to Leeward. For this reaſon you ought to compare the Quantity you fall to go to the Veſſel, to the Way you will make more than him in falling this Quantity; to the end you may ſee if this difference of Way will attain him, or fetch him; For otherwiſe, you wou'd fall into the Inconveniency of doing what we call *Engliſh Chaſe*, that is to ſay, falling to Leeward and a Stern. Theſe Conſiderations will be eaſy to examine, if you underſtand well the Third and Fourth Chapters, (ſetting aſide the Algebra) and this Chapter here.

One may ſee alſo (when one is chaſed, being to Leeward of the Veſſel that chaſes you) the moſt advantageous Courſe is that which follows the Line drawn from one Ship to the other; at leaſt if there be no Land to Leeward which hinders you; Or that being pretty near equally to Windward, or if you do not know that the Ship on which you are, has a great deal of advantage over the other, to go more near the Wind, which one may know in making ſeveral times the Obſervations of the Third Chapter.

ARTICLE IX.

The Third Uſe of the Second Figure is to determine the Situation of the Sail to go to Windward the moſt that is poſſible; For you have only to ſee which is the part of the Curve that is moſt to Windward, as here the Point L, which is at Twenty four Degrees, which ſhews that the Sail ought to make with the Wind an Angle of twenty four Degrees, to the end it may be in the moſt advantageous Situation to go to Windward the moſt that is poſſible: The Demonſtration is the ſame of that which has been given in the Sixth Article.

ARTICLE. X.

One may alſo make another Figure ſuch as the fourth Figure, which will have near the ſame uſe as the preceding, by making uſe of a Circumference of a Circle divided into unequal Parts in the Place of the Curve, of which we have given the Deſcription; the Conſtruction of this Fourth Figure is thus.

Draw at pleaſure B R, which repreſents the Line of the Wind, and B Z perpendicular to B R. Let R B be to B X as the Reſiſtance the Ship finds to ſplit the Water with its Side, is to the Reſiſtance which it finds to ſplit it with its Point; From the Point R, as Center with the Interval R X, deſcribe an Arch which cuts Z B in K, draw R K, make K L double of X B, draw L P parallel to K B, divide R B equally in two at the Point M, and R P at the Point Q, make B T equal to P Q, from the Point M, with the Interval M R deſcribe the Semicircle R F B, from the Point Q with the Interval Q R deſcribe the Semicircle R H P, from the Point B, with the Interval V taken at diſcretion, deſcribe the Arch V Z, from the ſame Point B, with the Interval B M deſcribe the Arch M S from the Point T, and with the ſame Interval B M deſcribe an Arch which cuts the foregoing in S, in fine, from the Point S, and the Interval S B, deſcribe a Circle B T N Y, one might have taken the Center of this Circle in all other Points of the Arch M S. Divide the Circumference

rence B F R into Degrees, or at leaſt at every five Degrees, from the Point B, at each of theſe Diviſions draw the Chords as B F at the Diviſion 60, which will cut the Circle Y N B in I, draw R F which will be cut in H by the little Circle R H P, take the Part R H and apply it from I to N, where you ſhall mark the Diviſion 60, do the ſame thing to have the other Diviſions of the Circle Y N B.

ARTICLE XI.

The Uſe of this Figure is the ſame with that of the foregoing, in taking the Diviſions of the Circumference Y N B in lieu of the Diviſions of the Curve, and the Demonſtration is a Conſequence of that of the ſecond Figure.

If one have taken the Point S for Center of the Circle Y N B, then the Diviſion of this Circumference, which it will interſect in B, will mark the Angle which the Sail ought to make with the Wind to go to Windward the moſt that is poſſible.

ARTICLE XII.

For to have a general Figure which ſhews the Situation of the Sail in regard to the Wind, in ſuppoſing what Proportion one wou'd of the Reſiſtance of the Water againſt the Side, to the Reſiſtance of the Water againſt her Bowgh, deſcribe the fifth Figure in this manner:

Let B R be the Line of the Wind, and B Y its Perpendicular; cut B R in two equally at the Point Q, B Q at the Point P, and B P at the Point *p*; From the Point Q draw at diſcretion Q M, which will interſect B Z in M, draw Q N parallel and equal to B M; divide Q M in 100 equal Parts, it ſuffices to mark every 5 unto 30, in the Points 5, 10, 15, 20, 25, & 30, From the Point N draw Lines to each of theſe Diviſions, which will cut Q P in the Points 5, 10, 15, 20, 25, & 30, from the Point *p* as Center, and with the Interval *p* B deſcribe the Semircircle B T P; from the Point P as Center, and with the Interval P B, deſcribe the Semicircle B G Q, likewiſe from the Points Q, 5, 10, 15, 20, 25, & 30, of the Line Q P, taken one after the other as Center, deſcribe the occult Semicircles which paſſes by B, and will cut Q R in the Points R, 5, 10, 15, 20, 25, & 30; In fine, from the Point B, and the Interval B R, or any other Interval taken at diſcretion, deſcribe the Arch R Z 60, which you ſhall divide from 5 to 5 Degrees, as the Figure ſheweth, draw occult Lines from the Point B to each of thoſe Diviſions, theſe Lines will divide into equal Arches the Semicircles which paſs by B.

For to deſcribe the Curves, do as in the Fifth Article; that is to ſay, Take one of the occult Lines, as B F, which cuts the little Semicircles in G and T, draw P T, which cuts B Z in Y, from the Point Y as Center, with the Interval Y G, deſcribe the Arch G 60, and from the Interval of each Interſection of the part G F, and the occult Circles, deſcribe the little Arches which cuts the Arch G 60 in ſeveral Parts, do the ſame thing to all other Lines like to B F, the little Arches being joined will deſcribe ſeven Curves like thoſe of the Fifth Chapter.

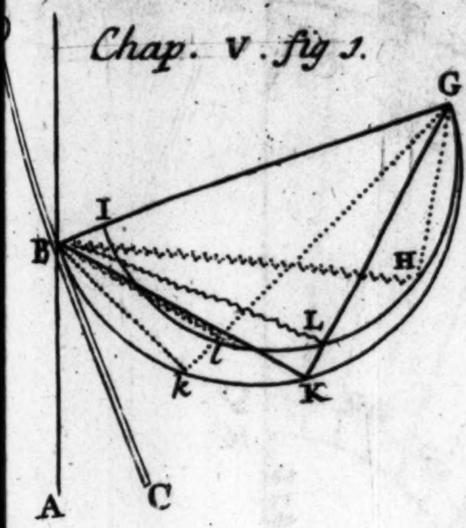
ARTICLE XIII.

For the uſe of this Figure, ſuppoſe that B E is the Courſe one wou'd keep, which makes with the Wind an Angle A B E of 126 Degrees, marked in the Arch R Z. I ſuppoſe the Reſiſtance of the Water againſt the Ship's Side to its Reſiſtance againſt the Bow is as 100 to 10, I take the Curve 10, which I find to be cut by the Line of the Courſe B E at the Diviſion H 60, which ſhews, that to keep the Courſe B E, the Sail muſt make with the Wind an Angle of 60 Degrees, which if this Reſiſtance had been as 100 to 20, one ſhou'd have found that the Sail ought to have made an Angle of fifty ſeven Degrees with the Wind.

It is eaſy to make a general Figure by the Method of the Tenth Article; the uſe of which will be the ſame with the preceding Figure.

ARTICLE XIV.

The Situation of the Sail, in regard to the Wind, having been determined by ſome one of theſe Figures, it is eaſy to find the Situation of the Keel, by the Method of the Fifth Chapter; and likewiſe one may make ſuch a Figure that ſhall ſhew all at once the moſt advantageous Situations of the Keel for any Courſe whatſoever.



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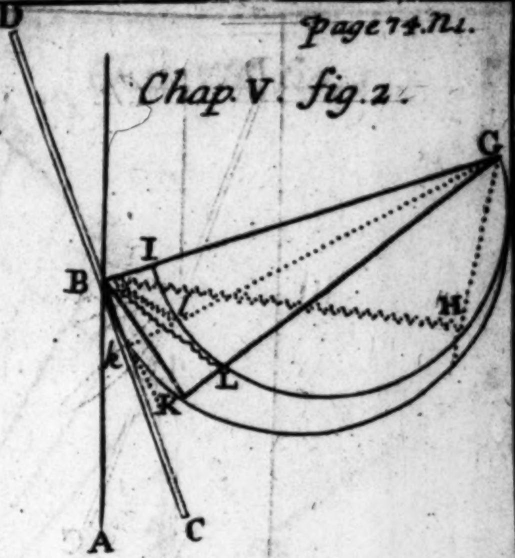

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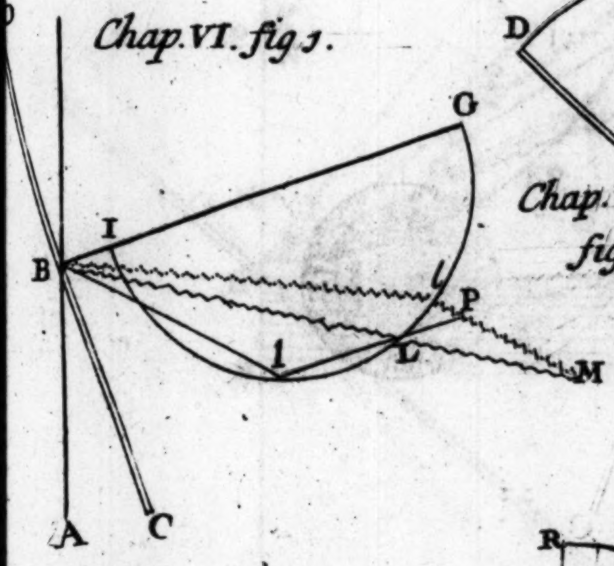

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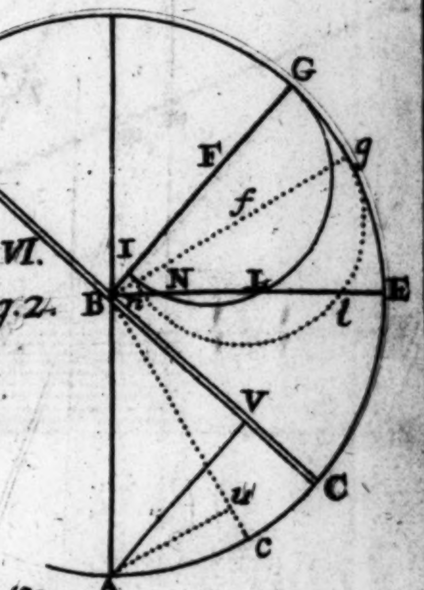

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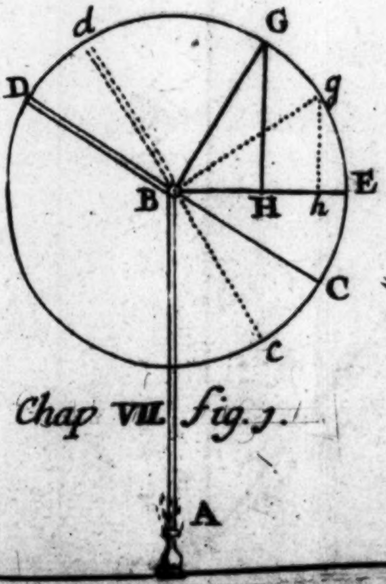

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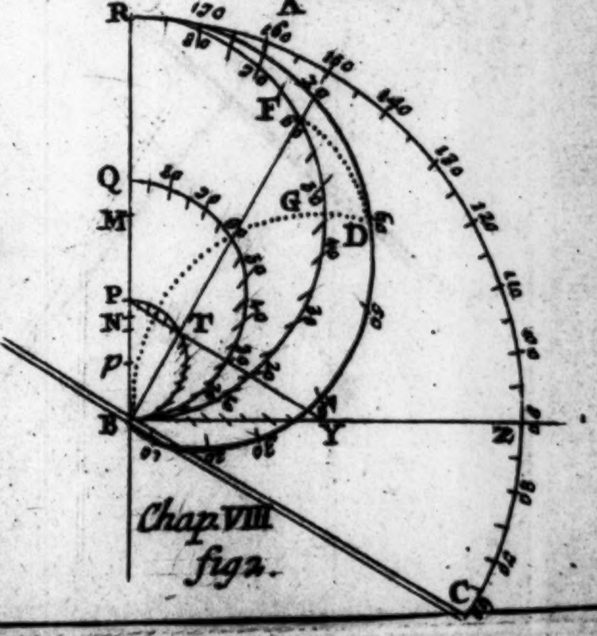

Chap. VIII fig. 2.

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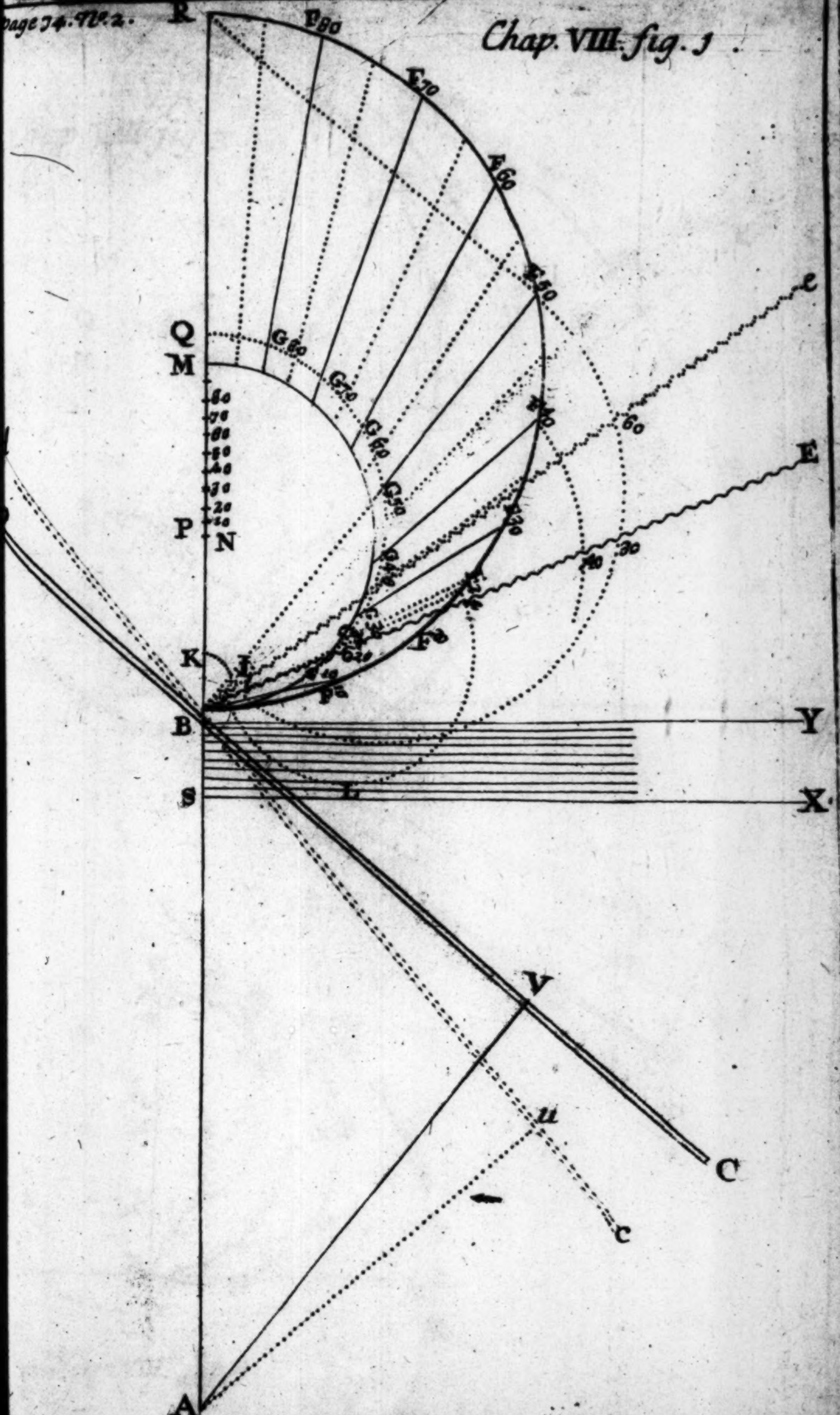
Chap. VIII. fig. 1



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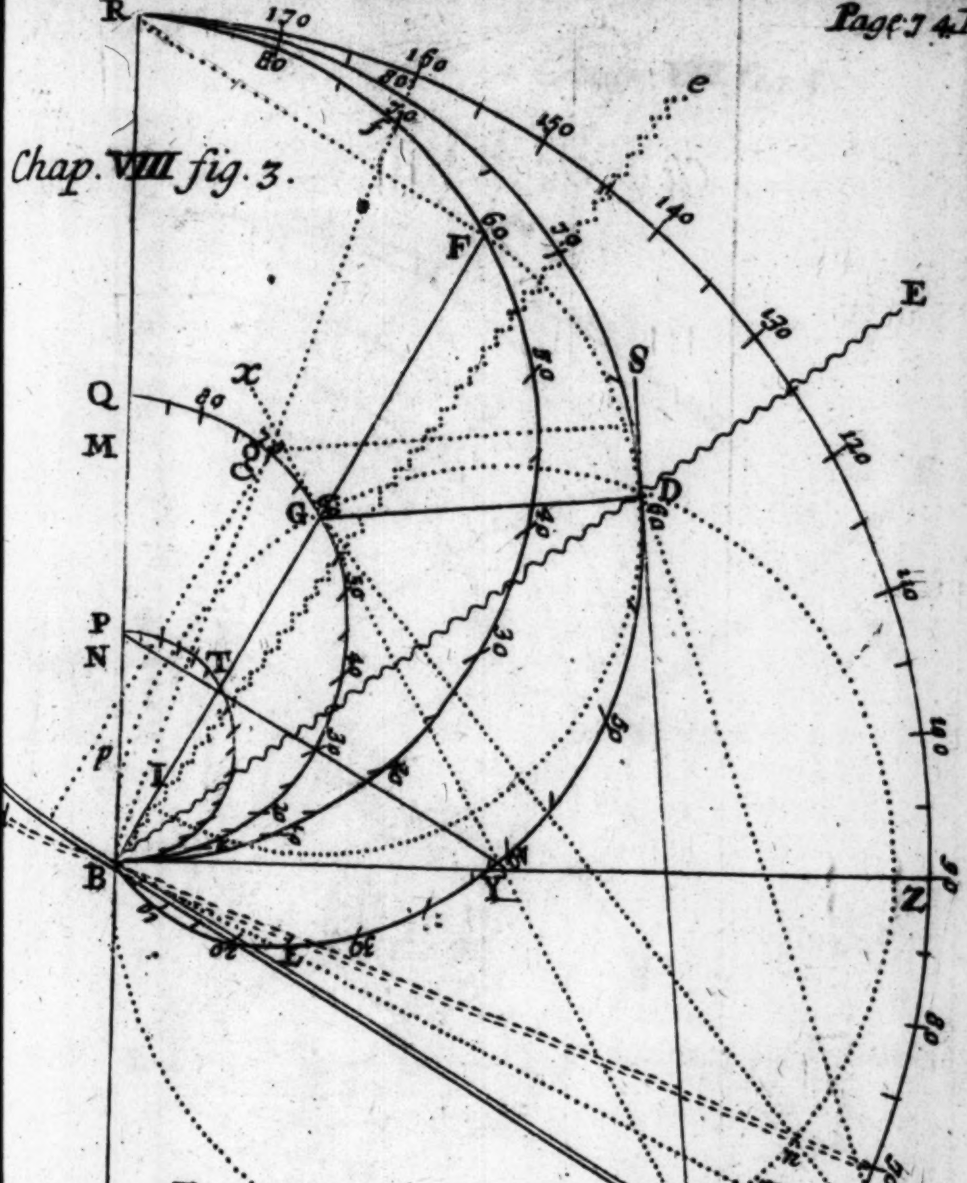

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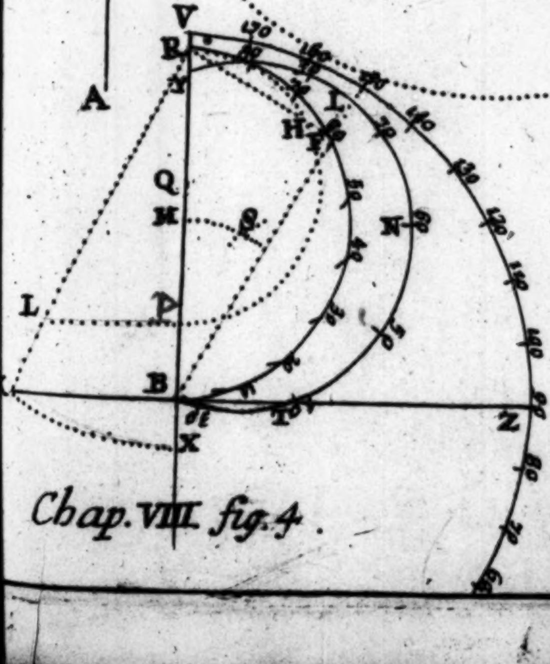

Chap. VIII. fig. 4.

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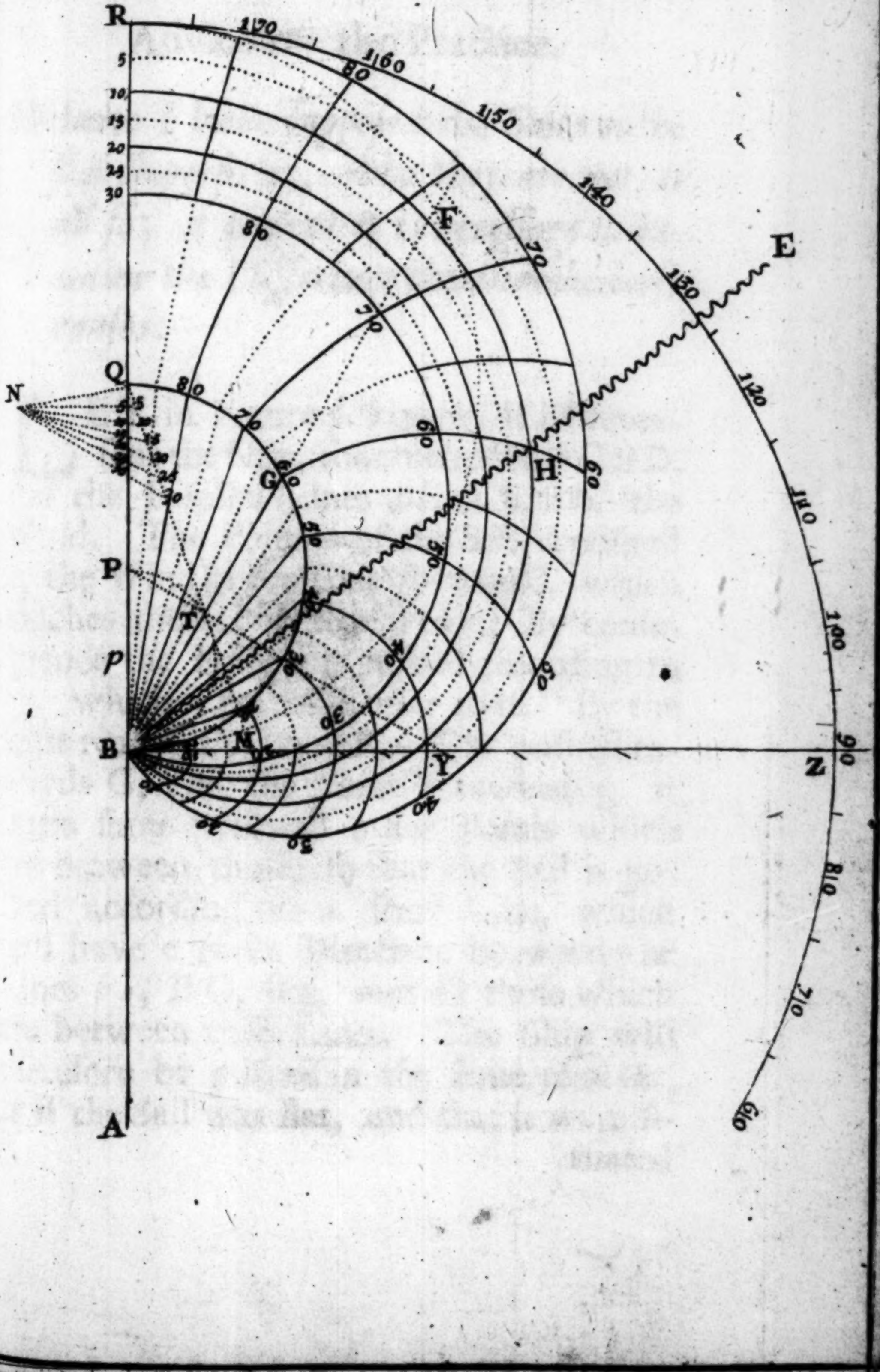
Chap. VIII fig. 5.



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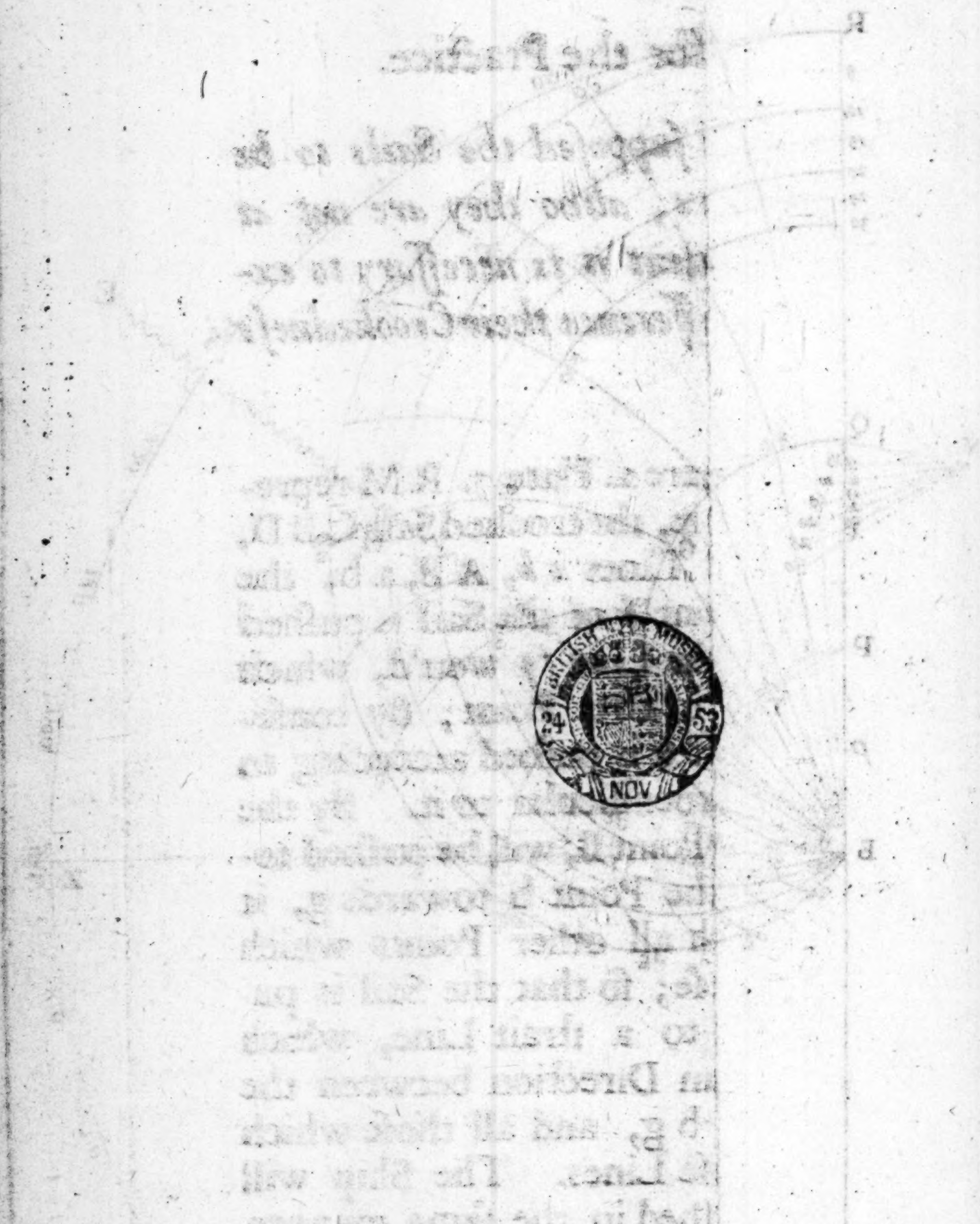

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CHAP. IX.

Advice for the Practice.

Hitherto I have ſuppoſed the Sails to be flat Superficies, altho they are not at all ſo; at preſent it is neceſſary to examine the Difference their Crookedneſs cauſes.

LET in Figure 5. Plate 7. R M repreſent the Ship, the crooked Sail C B D, and the Parallel Lines *a b*, A B, a b, the Wind. The Point *b* of the Sail is puſhed by the Wind as the Line *fp* wou'd, which touches the Sail in that Point; By conſequence the Point *b* is puſhed according to *bg*, which is perpendicular to it. By the ſame reaſon, the Point B, will be puſhed towards G, and the Point b towards g, it is the ſame with all other Points which are between theſe; ſo that the Sail is puſhed according to a ſtrait Line, which will have a mean Direction between the Lines *b g*, B G, b g, and all thoſe which are between theſe Lines. The Ship will therefore be puſhed in the ſame manner, as if the Sail was flat, and that it were ſituated according to a perpendicular Line, to the mean Direction, and it wou'd be puſhed by a mean Force 'twixt all the Forces, of whom the Sail is puſhed towards the mean Direction.

If the Line F P be the moſt advantageous Situation of the Sail, and that the Sail after having the Tack hail'd cloſe aboard, and the Sheet aft, makes the Curve D B C. It is evident, that the Parts of the Sail B C and B D are not in the moſt convenient Situation, ſeeing they are not ſituated according to F P, and that the Wind makes a too great Angle of Incidence with the part B C, and too ſharp an one with the part B D.

For to remedy this Fault as much as is poſſible, you muſt, as in the third Figure, carry forward the Tack from the Point D to the Point *d*, ſo that the Sail being ſtretched out, and the Foot touching the foremoſt Shroud, which ſuppoſe at the Point K, the part *d* B K will be approached, the moſt that is poſſible, to the Line F P. And one ought to have a little abaft the Point C of the Sail an Out-legger, as O *n*, which muſt be well faſten'd to the Side with a Knee, and with Shrouds; this Out-legger muſt be as far out as poſſible; at the End of which you muſt have a Block, in which your Sheet muſt go, whereby the part of the Sail B K C will be in the Situation B K *c*, the neareſt it poſſibly can be to the Line F P.

By this means or ſome other like, Ships may be kept to Windward with their low Sails a great deal more than they uſually are, which would be conſiderable, as well for to gain to Windward, or to go better than another Ship, as to get clear of a Lee-ſhore.

For it is to be noted that the difference of the Crookedneſs of the Sails, makes Ships hold the Wind more with their Top-Sails than with their Courſes, and that it is impoſſible to get off a Lee-ſhore with the latter, the reaſon is, the Top-ſails are ſtretch'd out along the great Yards as much as can be, before the Wind is let into them, ſo that the Wind can hardly make them crooked. It is not the ſame with the Low-ſails, for as ſoon as you begin to ſtretch out the Sail, the Wind gets in and makes ſuch a great Curve, in ſuch a manner, that you cannot flat them, becauſe it will require too great a Force, and alſo becauſe they are not drawn by the Sheets in the ſenſe they ought to be, for the Block, through which the Sheets run, being towards N, the Point C of the Sail is drawn towards it, and likewiſe the Shrouds retain it towards K, in ſtead of which it ought to draw it towards *n*, for to approach the moſt convenient Situation.

The Defect which comes from a too great Crookedneſs of Sail, is found yet more greater in the Gallies; for when their Sheets are haled cloſe aft, there is a part of the Sail which puſhes the Gally backward, and is entirely oppoſed to her run, and another part which only ſerves to make her drive to Leeward.

For to conceive this, Let in the fourth Figure R M repreſent a Gally, D B C the Sail, and the parallel Lines *a b*; A B, & a b the Wind; one ſees by what has been ſaid, that at the Point *b* the Ship is puſhed towards *g*, and at the Point B towards G; and as ſhe is puſhed ſideways in this Point, it only ſerves to make her drive; the Point b is puſhed towards g, which is a Stern, and by conſequence hinders her going a-head, in ſuch manner, that if the Line *f p* be the moſt advantageous Situation of the Sail, the Part *b* D wou'd be very near this Line, and the part B C would be very far off.

For to place the Sail moſt advantageouſly there wants a Tackle at the Point *b* to keep the part D *b* as it is, and afterwards to boom out the Lee-ſheet with an Out-legger, which may puſh the Point C towards *c*, and to put the part *b* C in the Situation *b c*, the moſt approaching it poſſibly can to the Line *f p*.

It will be neceſſary to have regard to theſe Crookedneſſes when one would make the Proof of the Second Article of the Second Chapter for to know the Proporrion 'twixt the Reſiſtance the Ship finds to divide the Water with its Side, to the Reſiſtance ſhe finds to divide it with her Point or Stem: For you muſt take the Wind perpendicular to the Sail, to the end it may be uniform, and that the mean Force may be perpendicular to the Yard: One ſhall know by this means to what Side the Ship is puſhed. For to be more ſure, one ought to make a great many Trials, in putting the Sail in divers Situations, and making the Ship to go towards divers Parts, by reaſon of the Currents which may be met with; and you muſt take a medium 'twixt all theſe Trials.

It muſt alſo be obſerved, that the Ship ſhould be always in the ſame Trim; that is to ſay, that ſhe ought to be in the ſame Situation in regard to the Horizon Line, to the end ſhe may always encounter the Parts of the Water in the ſame faſhion, and that alſo the Relation of the Reſiſtance of the Side to the Point ſhould be always the ſame. For this effect, the Ship muſt not only draw the ſame Water afore and abaft at one time as ſhe does at another, but alſo as much as poſſible, the Loading of the Ship muſt always be diſpoſed in the ſame manner: Otherwiſe, the Waves making the Water to leave the Ship, ſometimes afore and ſometimes abaft, the Equilibrio of the Ship would vary, and ſhe would pitch more or leſs, which would cauſe ſome Change in this Relation. By the Obſervations of the Second Chapter one may put the Ship in the moſt advantageous Situation, in relation to the Horizontal Line. In regard to the Loading it muſt be diſpos'd as near the Main-maſt as it poſſibly can; For then the Extremities being leſs charg'd than they might be, the Ship will not plunge in ſo violently when the Water leaves her; in ſuch manner, that the bluff Part of her Bough not entring ſo far in the Water, the Ship will not find ſo much Water to puſh before her.

It ought to be remark'd in the Seventh Chapter, that conſidering rigorouſly the Angle which the Rudder ſhould make with the Keel, it will not be preciſely of the Greatneſs which is ſaid. For when the Rudder is in the Situation B D the Ship is puſhed Sideways according to B E, the Quantity B H, and a Stern according to H G, the Quantity H G. When the Rudder is in the Situation B *d*, the Ship is puſhed ſideways the Quantity B *h*, and a Stern according to *h g*, the Quantity *h g*; ſo that the Ship is more puſhed a Stern when the Rudder is according to B D, than when it is according B *d*, in the ſame Ratio that H G is greater than *h g*. Conſequently the Ship will loſe more of its Air, that is to ſay, its Swiftneſs, and the abſolute Force of the Water will not be ſo great when the Rudder is according to B D, as when it is according to B *d*, to which may be added, that the Ship does not move according to the Direction of its Keel, but a little ſideways, becauſe of the Drift or Lee-way, ſo it may not be ſaid rigorouſly that the moſt perfect of all is marked: it ſhould be ſomething leſs, becauſe of theſe Differences, but as they are not ſenſible this Angle is the moſt approaching that is poſſible, and it is always the greateſt Angle the Tillar of the Rudder ought to make with the Keel, and it is an Advantage to put a Cleat at that part which terminates this Angle, as has been ſaid in the Seventh Chapter, to the end that the Tillar may not be put over too far.

As to the means of putting the Sail in the moſt advantageous Situation, after this Situation ſhall be known by the aforegoing Methods, you may put Marks to the Sheets, and to the Braces, and alſo to the Bowlines, for to know when the Sail ſhall be in this Situation. For, by Example, when the Marks of a Brace or a Sheet ſhall come to its Cleat [after one ſhall have put this Mark for to come juſt to this place] one ſhall be aſſured that the Sail trims well, although it ſhould be in the Night.

It muſt be obſerved, that theſe Marks ought to be put only to the Braces of the great Yard, becauſe they are always of the ſame height. There muſt be none to the Braces of the Top-Sail and Top-

Gallant Yards, becauſe they are hoiſed more or leſs, and ſo the Place of theſe Marks wou'd vary, but the great Yards being in the Situation they ought to be, it will be eaſy to regulate the others by theſe.

FINIS.

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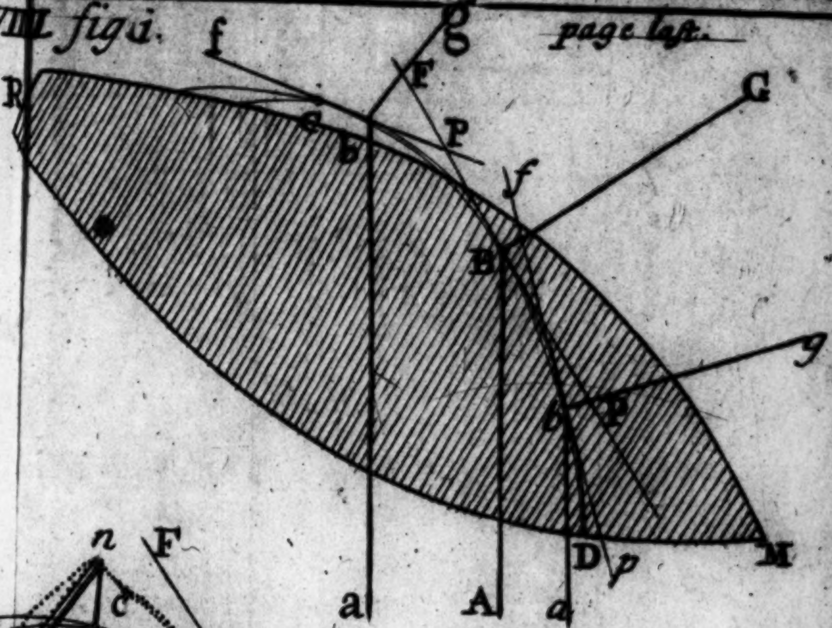

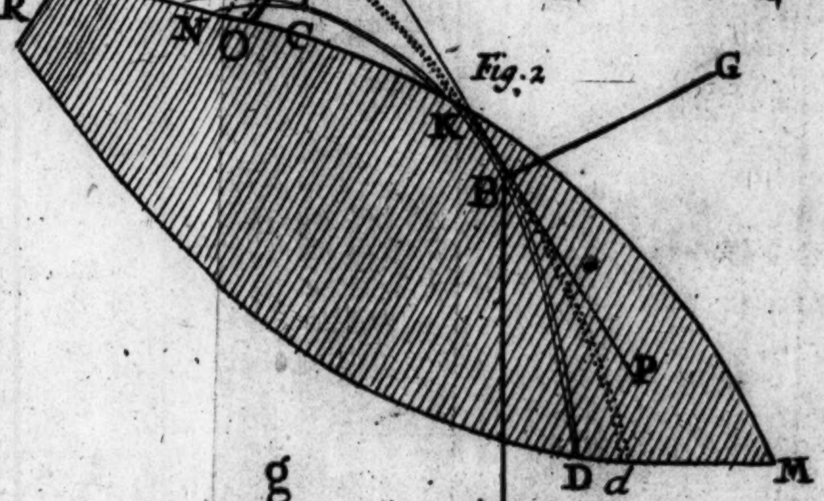
Fig. 2

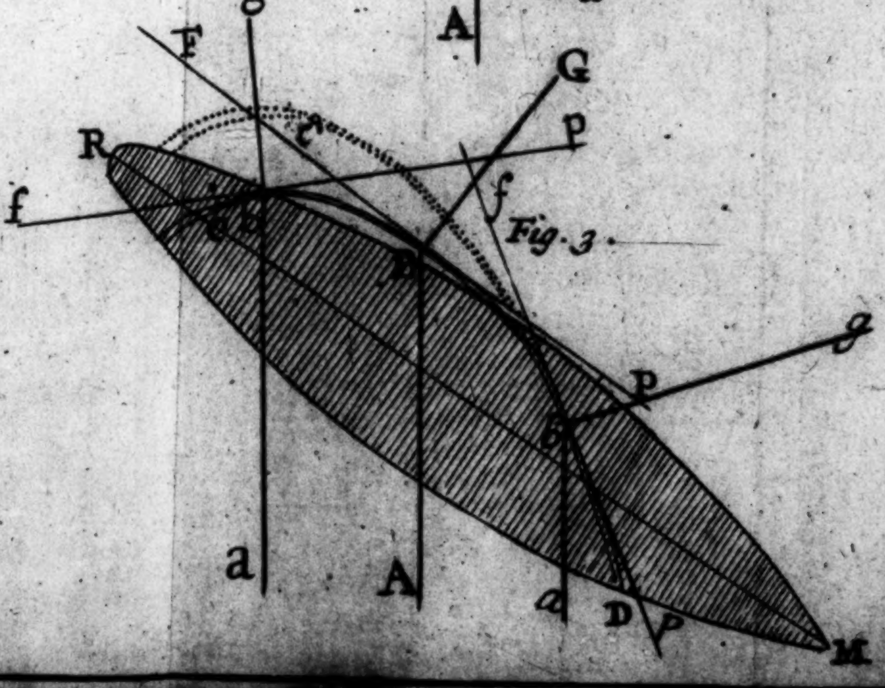
Fig. 3